AIEE PROCEEDINGS
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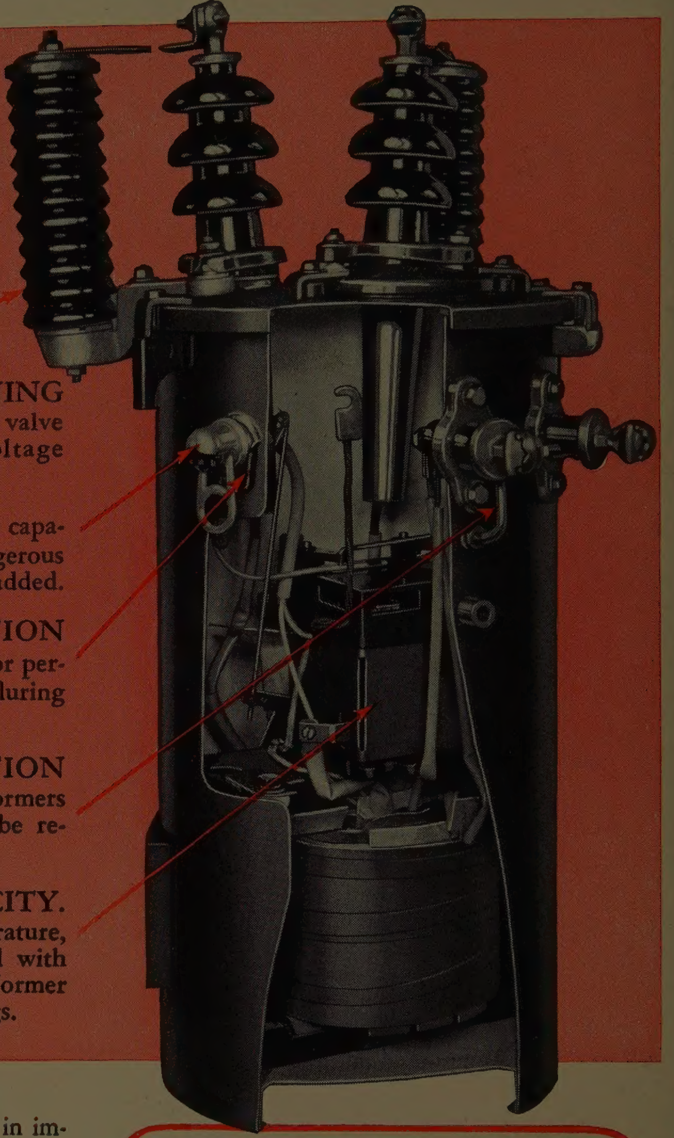
ELECTRICAL ENGINEERING

JULY 1950

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Improve Consumer Service

...with ACP* Transformers



1. **NO INTERRUPTIONS FROM LIGHTNING** — even under severe surges. Arresters in either valve or expulsion type can be specified. High voltage protective links guard against feeder lockouts.

2. **LOADS DON'T OUTGROW** transformer capacity unnoticed. Signal light warns against dangerous overload conditions, and more capacity can be added.

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4. **LOW VOLTAGE SURGE PROTECTION** is provided by low voltage neutral gap on transformers with two high voltage bushings. Can easily be removed and replaced with a ground strap.

5. ***MORE* USEFUL OVERLOAD CAPACITY.** Secondary breaker, operated by either oil temperature, excess current or both, is closely coordinated with transformer thermal characteristics — lets transformer operate right up to actual safe limit of windings.

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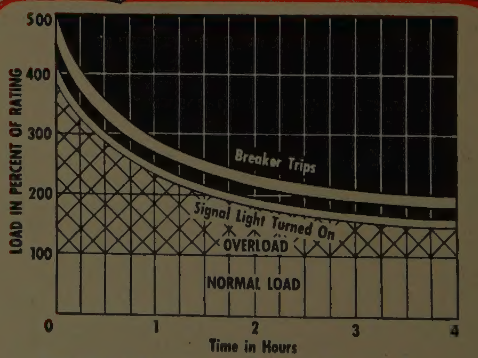

Typical load-time curve for an ACP transformer shows how breaker increases useful capacity.

A-3076

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ELECTRICAL ENGINEERING

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JULY
1950

The Cover: What can happen to an electric contacter switch at high altitude in an airplane is being demonstrated in the new Boeing Airplane Company electrical laboratory at Seattle, Wash. The contacter inside the bell jar, is being tested with an excessively heavy power load, thus causing arcing in the thin atmosphere equivalent to that of 50,000 feet above the earth's surface. Boeing Airplane Company photo

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VOL. 69 NO. 7

Statements and opinions given in articles appearing in *ELECTRICAL ENGINEERING* are expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on controversial matters. Published monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

Headquarters
33 West 39th Street
New York 18, N. Y.

Editorial Offices
500 Fifth Avenue
New York 18, N. Y.

HIGHLIGHTS........

Is Engineering a Profession? In his discussion of the question, AIEE President Fairman presents some of the criteria by which a profession is usually judged—education, scholarship, ministry to the public—and then evaluates engineering in the light of these standards (*pages 579–82*).

Digests. Short authors' digests of conference-type papers presented at two meetings held during May are included in this issue. The first of these was the Great Lakes District Meeting in Jackson, Mich., May 11–12 (*pages 638–40*). The other was the Conference on Telemetering in Philadelphia, Pa., May 24–26 (*pages 641–3*). A Report of the latter conference including all papers and related discussion, may be obtained from AIEE Headquarters for $3.50.

Tribute to Heaviside. This year, 1950, marks the hundredth anniversary of the birth of Oliver Heaviside, and President Buckley of the Bell Telephone Laboratories pays tribute to the man whose work had such an important influence on the science of electrical communication (*page 587*).

Alco-GE Locomotive. Based on analyses of current requirements for a freight locomotive showing a low initial investment, low fuel cost, and low maintenance cost, the Alco-GE gas-turbine electric locomotive was developed. The control and characteristics of the unit are essentially the same as those of the modern diesel-electric locomotive (*pages 583–6*).

A New Transformer Insulation. A product developed during the war, butyl has properties which make it emminently suitable for use as an insulation in instrument transformers operating under 15,000 volts. It has a higher dielectric strength, a smaller 60 per cent power factor, greater resistance to mechanical damage, and absorbs less moisture than the commonly used asphalt-impregnated paper. Since butyl is molded over the transformer components, a continuous and homogeneous distribution of the insulation is assured (*pages 594–9*).

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The Consulting Engineer. In this article, the author, a consulting engineer, discusses the responsibilities of a member of his profession. These are not only the basic responsibilities which the consulting engineer has in common with all engineers, but also the particular responsibilities which are imposed upon him, particularly in his relationship to management (*pages 589–92*).

Mathematics in Engineering. In recognition of the extensive use of mathematics in engineering, the AIEE Committee on Basic Sciences has created a Subcommittee on Mathematics which will include prominent mathematicians. Under a new policy, recently announced, members are invited to submit engineering problems to the subcommittee for possible solution (*page 606*).

Mechanism of the Spark Breakdown. L. H. Fisher of the New York University Department of Physics traces the development of the present concepts of the physical processes which lead to the d-c electric spark and discusses the extent to which these processes are understood. The discussion is limited to electrical breakdown in air, in a uniform field, and at pressures between atmospheric and a few centimeters of mercury (*pages 613–19*).

Military Storage Batteries. Low-temperature operation of storage batteries presents more problems than high-temperature operation. During World War II, the lower temperature limit was set at −40 degrees Fahrenheit, but since then temperature limits have been extended so that subzero operation has become even more difficult (*pages 619–21*).

Power Transformers. The experiences of engineers of the American Gas and Electric Company in the selection, design, and operation of power transformers for the most economical performance is discussed. All of the various types of transformers used in a system are included in the discussion, and many of the maintenance practices in use are described (*pages 600–04*).

High-Voltage Oil Circuit Breakers. Described in this article are some of the special design features for steel-tank oil circuit breakers rated 5,000,000 kva at 138 kv, 161 kv, and 230 kv, and rated 7,500,000 or 10,000,000 at 230 kv. The method of verifying these interrupting capacities, both in the manufacturer's high-power laboratory and by field tests on the customer's property, is outlined, and special consideration is given to the problems of switching line-charging currents and interrupting high power repeatedly under both standard duty and rapid-reclosing duty cycles (*pages 629–34*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions*.

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Jul '49, p 47A	South West District Summer General
Nov '49, p 51A	Pacific General Fall General
Feb '50, p 46A	Winter General (1950)
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General (1950)

Verification of Electromagnet Propositions. Four problems concerning the magnetic fields surrounding current-carrying conductors are discussed by A. D. Moore of the Electrical Engineering Department of the University of Michigan. He uses illustrations obtained by the use of his invention, a fluid field mapper, to give a pictorial representation of a 2-dimensional field around long conductors (*pages 607–10*).

Industrial Television and the Vidicon. Television in industry has many important applications, mainly because of its ability to extend human sight. In this article, by V. K. Zworykin, Vice-President and Technical Consultant of the Radio Corporation of America, the vidicon pickup tube's role in industrial television applications is described (*pages 624–7*).

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices, 500 Fifth Avenue, New York 18, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. July 1950, Vol. 69, No. 7. Number of copies of this issue 52,600

Is Engineering a Profession?

JAMES F. FAIRMAN
PRESIDENT AIEE

IN DISCUSSING the question—is engineering a profession?—it is logical to begin by defining what we mean by a "profession." If we have a common understanding as to what a "profession" is, we may then be able to ascertain whether or not our particular calling is or could become a "profession." In the process we should obtain a clearer conception of what it means to belong to a profession in terms not only of the privileges and rewards, but in terms of the obligations as well.

One suspects that some, if not much, of the confusion which impedes our thinking and acting in all fields of human activity arises from a lack of a common understanding of familiar words, of which that much abused word "democracy" is perhaps the best example. Some of the confusion is due to our carelessness in the use of words, to our tendency to exaggeration and the use of superlatives in the Hollywood manner when under emotional stress or when trying to put an idea across; but some of the confusion seems deliberately to be created for the purpose of confusing or misleading. A familiar example in our own field of activity is the misuse of the word "engineer," sometimes carelessly by the public, but too often deliberately by persons who seek to mislead the public for their own advantage. Deliberate misuse of a word occurs only when the "misuser" hopes to gain some end which he would be less likely to achieve if he relied solely on the merits of his case. So in spite of our annoyance or indignation at the misuse of the term "engineer," we engineers may find some cold comfort in the fact that an engineer must be considered a superior sort of person, at least by that sector of the body politic who try to pass themselves off as engineers.

A profession requires education, it implies scholarship, it involves mental rather than physical labor, it ministers to the people. Judging by these criteria, it would seem that the engineer can conclude that his calling is a profession; however, he must be willing, both collectively and individually, to go that "second mile" of voluntary effort if the public also is to accept it as such.

THE QUALITIES OF A PROFESSION

THE dictionaries convey the idea that a profession is an occupation which requires a liberal, if not a specialized, education and which involves mental rather than manual labor; that a profession implies scholarship as in the case of the learned professions of law, medicine, and theology. The fact that these three are generally cited as examples of what a profession is, suggests that service to society or ministry to the people is an important characteristic of a profession.

In this short article I cannot elaborate on this characteristic. The subject has been covered most ably by a number of distinguished members of our own and other professions. If you have not already done so, I urge you to read "The Second Mile," by W. E. Wickenden, published in a number of the engineering societies' journals (*EE, May '42, pp 242–7*) and reprinted in pamphlet form, copies of which are still available through engineering societies headquarters in New York. In his opening paragraph, Dr. Wickenden says:

"Every calling has its mile of compulsion, its round of tasks and duties, its code of man-to-man relations, which one must traverse day by day if he is to survive. Beyond that lies the mile of voluntary effort, where men strive for special excellence, seek self-expression more than material gain, and give that unrequited margin of service to the common good which alone can invest work with a wide and enduring significance. The best fun of life and most of its durable satisfactions lie in this second mile, and it is only here that a calling can attain to the dignity and distinction of a profession."

For those who may be interested in at least one more reference, I recommend "The Qualities of a Profession," by Vannevar Bush (*EE, Apr '39, pp 156–60*). That deserves a wider reading than I expect it has received. In support of my thesis, I offer this quotation from Dr. Bush:

"In every one of the professional groups will be found the initial central theme intact—they minister to the people. Otherwise they no longer endure as professional groups.

". . . Ministry carries with it the ideas of dignity and authority; it connotes no weakness, and offers no apology. . . . There is no fog of subservience surrounding the concept. The physician who ministers to his client takes charge by right of superior specialized knowledge of a highly personal aspect of the affairs of the individual. The attorney assumes professional responsibility for guiding the legal acts of his client, and speaks with the whole authority of the statutes as a background. It is in this higher sense that we trace the thread of ministry to the people.

"This is the fuel which has kept alight through many ages the professional spirit. Every time that the fuel has become exhausted, the light has gone out. It has not mattered how much was retained of trapping and mysticism, nor what the profundity of utterances, there has been no

Full text of the presidential address presented during the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950.

James F. Fairman is Vice-President, Consolidated Edison Company of New York, Inc., New York, N. Y.

true profession that has not with dignity and authority advised and counselled the people, that has not guarded the commonweal. For a true profession exists only as the people allow it to maintain its prerogatives by reason of confidence in its integrity and belief in its general beneficence."

I shall not presume to formulate a definition of the word "profession." I shall content myself with this mention of some of the things it means to me, and I shall hope that it may mean some of these same things to you.

Assuming that you are willing to accept this concept of a profession, let us consider whether or not our particular calling, engineering, is entitled to be accepted by the people as a profession. Let us bring to our inquiry the quality of objectivity which we sometimes claim as if it were the exclusive possession of engineers. Let us have the humility to assume that if we are not understood by the public the fault may be partly our own. In other words, let us make a professional approach to the problem.

Here again, I can only suggest a line of inquiry directed toward finding the affirmative answer which I believe can be made to the question.

A profession requires that its practitioners be educated. Well, engineers receive an intensive education, rather more on the specialized than on the liberal side, to be sure, and of generally shorter duration than the practitioners of the learned professions. It is just possible that engineers would be better engineers and better citizens if they were required to undergo a longer and broader, as well as a more rigorous, training. More of them might be able to get on their feet and talk effectively on those matters affecting the public welfare on which engineers are more competent to speak than many of those who do lift their voices. If more engineers took an active and constructive interest in public affairs, the public might hold engineers in greater esteem. They might more readily recognize engineers as members of a learned profession.

A profession involves mental rather than manual labor. We engineers do most of our work with our heads rather than with our hands. Our intellectual labors are as arduous, our decisions are as difficult, our responsibility for favorable results as heavy as those of the practitioners of other professions. People may sense this but they do not really understand what we do because they do not often see us at work. They do not have, and perhaps never can have, the type of intimate contact with our labors as they do have with the practitioners of more personalized professional services. But we should be clever enough to give the public a more accurate picture of engineers at work than is currently presented in the movies, popular fiction, and the press.

A profession implies scholarship. There is a great deal more scholarship in our fraternity than is generally realized even by ourselves. With a few notable exceptions, however, the public is more likely to associate scholarship with the pure rather than the applied scientist because the light of the latter is so apt to be hidden under a corporate or governmental bushel.

A profession ministers to the people. Engineers minister to the people by their many contributions to the health, safety, comfort, and convenience of the public. Our ministry is just as real, but it is usually applied in providing goods and services for people in the mass rather than personal service for an individual citizen. It is not surprising that the average citizen is more conscious of the "engineer" in the cab of the locomotive than he is of the engineer who designed the locomotive and the many other parts of a modern railroad system by which the citizen is enabled more quickly to accomplish his errand in comfort and safety.

Much of the discussion of the subject of professional recognition by the public which I have heard seems to have been concerned principally with the possible connection between public recognition of engineering as a profession and improved economic status of engineers. It is natural that we should be concerned about our economic status and certainly there is nothing wrong about our trying to improve it. But we must not overlook the fact that the methods we use in seeking to improve our economic status will tell the public a great deal about whether or not we are really professional in our outlook, whether or not we put ministry to the people and devotion to our calling above personal gain. If our aspiration for professional recognition arises principally from our desire for better economic status, we may gain the latter at the expense of the former. We must not expect professional recognition, by some peculiar magic of its own, to produce or guarantee an improvement in our economic position. It will help, but it is only one of a number of factors of equal or greater significance.

DOES ENGINEERING MEASURE UP?

The line of inquiry which I have touched on in only a most superficial way, suggests that we may reasonably conclude that our calling has the earmarks of a profession, that it has the potentialities of a learned profession, but that whether or not it will be so recognized by the public depends on you and on me, on our ability to overcome some of the handicaps seemingly inherent in our lack of intimate professional relationships with the public, and on whether we look and act as they expect professional people to look and act.

Public opinion is a cumulative thing and is formed as a result of a series of impressions over a period of time. The older professions have set certain patterns by which the public appraises the newer professional groups. In addition to the criteria already mentioned, what would one expect to find as a distinctive mark of a professional group?

Probably the first thing which would come to mind would be an organization of the professional group devoted to the public welfare as well as to the protection and advancement of the legitimate interests of the group. Engineers have plenty of organizations but those organizations have shown little tangible concern for the public welfare and have been singularly ineffective in protecting the legitimate interests of their members. They have served primarily as forums for the exchange of technical information and have been an important factor in the advancement of the art and science of engineering in its

several specialized branches. These organizations functioned in the way they were designed to function and rendered the service desired by their members. Most of these organizations, for reasons which seemed good to them, offered the privilege of membership in some form to individuals who were not professionals in the sense we are using that word. As is natural in the independent development of separate groups, there was no uniformity in nomenclature or in standards of membership and even their codes of ethics differed in phraseology and in emphasis. How could the public be expected to distinguish engineering as a profession when the engineers themselves could not decide who was an engineer, what he should be called, what ethical standards should govern his professional relations to others, and how to build an organization to speak for them as a professional group.

Sometimes I think that we have put too much emphasis on the matter of organization and have come to think that if only we devised the right kind of organization all our problems would automatically be solved. Of course, this is not so. Any organization is only the means to an end; an instrument or tool, by the use of which a group of people having common interests hope more efficiently or more effectively to attain their objectives. We should treat our organizations as such. We should be willing to use them and by using them determine their limitations as well as their merits. We should modify them to meet new situations and we should scrap them when they are obsolete or worn out. The difficulty with human organizations is that they become so mixed with our sentiments and our prejudices that we frequently blind ourselves to their limitations and delay a much needed job of renovation or renewal.

Recognition of this unsatisfactory state of affairs by engineers is not a new thing. I have heard about it all my professional life. Many of us would like to change it. The difficulty is we cannot seem to agree on how to go about it, let alone what the final solution should be. As I look back on past and present efforts to unify and strengthen the profession, it seems to me that there have been at least three handicaps; some of our schemes have been too ambitious, some of them have been too remote from the individual, and the majority of our brethren in engineering have not had very fully developed professional consciousness.

Grandiose schemes fail because they exceed our ability to carry them out. Individually, we lie back and depend on or wait for others to do the job. If we would be content to start more modestly, if we would accept what each of us could do within his own abilities and limitations, and if we would learn to co-operate, I believe we would be astonished at what we could do.

However worthy the objectives of an organization may be, if its operation and personnel are so remote from the individual engineer that he has no feeling of belonging and has little or no knowledge of its activities, is it surprising that it arouses so little interest and enlists so meager support among the rank and file of the profession? Individual membership, individual participation in its activities, and individual payment of dues in furtherance of its objectives would seem to be requisites for any constructive and aggressive organization of professional people.

We do a lot of preaching about the development of professional consciousness and then proceed to undermine our gospel. One example is the method in which we seek new members. We expend a considerable amount of our efforts and resources in the activities of our membership committees, in the preparation and distribution of pamphlets and other literature generally playing up what the organization has to offer the individual for his dues rather than what the individual can do for his profession and for society. We take pride in the size and rate of growth of our organizations as if that were a worthy end in itself. We worry about the adverse effect on our size or rate of growth if we should attempt to be realistic about the dues necessary to carry on and expand the work for which the organization was created. Without intending to do so we thereby tend to depreciate our organizations and our profession in the eyes of our members, prospective members, and the public. Let us stop being afraid. Let us stop being apologetic. Let us stop making membership easy. Let us begin asking the prospective member what he has to give that will be good for the organization. Let us raise our standards and our price. Let us dare to take risks to promote a sense of obligation to our calling and to society. Until more engineers volunteer for membership and service in their organizations, each asking what can he give to it rather than what will he get out of it; in other words, until more of us are imbued with a keener sense of professional responsibility, we shall continue to be handicapped in accomplishing the purposes for which any of our organizations exist.

WHAT THE INDIVIDUAL CAN DO

I HAVE been asked, "What can we do as individuals?" My answer runs like this. If we see a job that needs doing, and if we want to have it done, and if we are willing to exert ourselves to help do it, I suggest that we start with ourselves and with those most closely associated with us in our own communities. Each of us should do his own job by which he makes his living to the best of his ability. Each of us should continually prepare himself for greater responsibilities and for greater opportunities. Each of us must not only talk but act as a professional man. Acting as a professional man involves membership in at least one organization devoted to the advancement of the art and science of one's particular specialized branch of engineering. But one's activities should not be confined to his specialized technical field. Each of us should support work in the broader field of his professional interest by whatever mechanism is at hand or by joining with his fellows in the development of a mechanism appropriate to their local problems. Each of us should be active in some local civic organization, thereby demonstrating to people in other walks of life that engineers are not narrow, antisocial specialists.

I think most of the people who have discussed this subject would agree with these suggestions for individual action. I submit two more for your consideration. First, I suggest that each of us recognize the facts of life as they

exist today in the field of professional licensure. Let us stop arguing about whether or not it should be and devote ourselves to making it what it might be—another useful instrument for the advancement of the profession and for the protection of the public.

Second, I suggest that each of us recognize that the great majority of engineers work for other engineers and that the latter, smaller group has a professional obligation to the larger group. Speaking as one of that group legally classified as an employer to those in similar positions, may I point out that each of us can influence, and sometimes even control, the professional development and the economic status of the engineers under our direction. Let us not be too busy to give some attention to that obligation. Specifically, let us not use the title "engineer" in any form for people who are not engineers or for positions which do not require engineering training or experience. Let us not assign engineers to jobs which are not engineering. Then let us pay salaries to those in real engineering positions commensurate with their individual training, experience, and ability and let us treat them as we would like to be treated, both in our economic and professional relationships. Let us be sure that we put our professional ideals into practice in our own offices and shops. If we do so, many of the problems of the employee engineer will be well on the way to a solution.

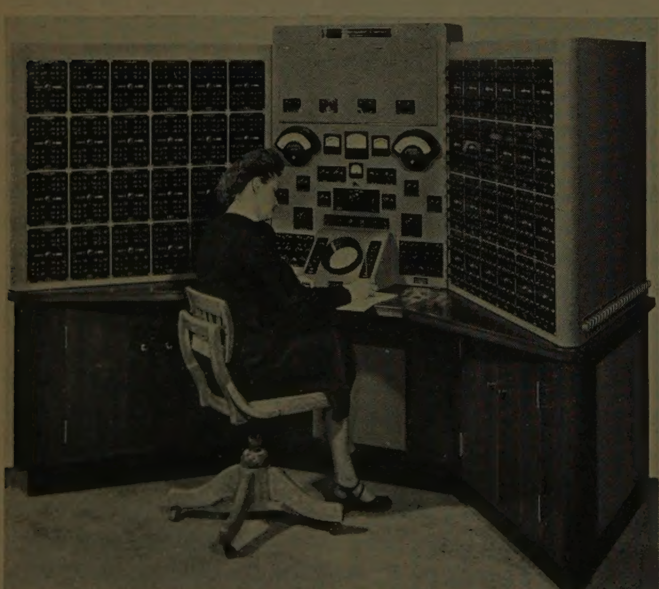
If each of us will go the second mile in all these relationships, if each of us will minister to the people to the best of his ability, we shall make more rapid progress in attaining recognition as members of a profession. We may even succeed in improving our economic position, and in developing an organization of and for the whole profession which will be a more perfect instrument for the continuous advancement of the profession and for constructive public service. When we shall have accomplished these things, there will no longer be any occasion to discuss the question: "Is engineering a profession?" The answer will be taken for granted and we shall be free to devote all our talents and energies to the carrying out of our obligations as professional men and citizens.

New Electronic Principal-Strain Computer

A new electronic computing instrument for automatically computing and indicating principal strains has been developed and built by the Hathaway Instrument Company for the National Advisory Committee for Aeronautics. The new computer is now in operation at Langley Field, Va.

This computer, which is shown below, operates directly from strain-gauge rosettes, indicating almost instantaneously the values of major principal strain, minor principal strain, and the principal angle.

Principal strains are determined experimentally by means of the strain-gauge rosette, which is an arrangement of three or four resistance strain gauges mounted on the surface under test at definite angles with each other. The voltage outputs of each gauge are translated into strain, and then these individual strain values are placed into equations or formulas which yield the desired values of principal strains and the principal angle. Equations differ for different arrangements of gauges in the rosette, but all equations involve sums and differences and square roots of sums and/or differences squared.



The principal-strain computer operates with equi-angular rosettes, rectangular rosettes, and with T-Δ rosettes. To convert from one equation to another, it is merely necessary to operate a single selector switch.

The sum and difference factors are obtained by networks, operating directly on the outputs of the individual gauges. The square root of the sum of several squares is obtained almost instantaneously by a self-balancing electrodynamometer.

The rosettes are powered by a 400-cycle carrier and all operations in the calculations are performed on this carrier without any modulation or demodulation. Wave form and frequency are not critical.

A total of 48 rosettes, either of the 3-gauge or 4-gauge variety, may be connected to the computer and each gauge properly balanced before strain determinations are made. After each increment of strain is applied, the operator can read and record the major and minor principal strains and the principal angle as rapidly as he can operate the rosette selector switch and read and tabulate the data.

Built-in calibrating equipment is provided for quick and precise calibration of the rosette to the indicators.

Alco-GE Gas-Turbine Electric Locomotive

A. H. MOREY

Basic design features of the locomotive described in this article were dictated by current railroad needs. The keynote is simplicity, as far as this is compatible with the application of a new type of prime mover to railroad motive power. The result has been a unit with control and characteristics essentially the same as those of the modern diesel-electric locomotive, except where power-plant characteristics required or permitted advantageous differences.

THE ALCO-GE gas-turbine electric locomotive, shown in Figure 1, is designed for freight service. It is an 8-axle 8-motor *B-B-B-B* locomotive weighing 253 tons (average) and rated at 4,500 horsepower for traction (at 80 degreees Fahrenheit and 1,500-feet elevation). The locomotive is 83 feet, $7^1/_2$ inches long, and 14 feet, 3 inches high over the roof sheets. It will negotiate curves of 288-feet radius.

This locomotive is designed to burn grade-6 fuel oil with some restrictions. Its specific fuel consumption is relatively high compared to diesel-electric locomotives, and low compared to oil-burning steam locomotives.

The general design, especially the power rating and weight of the locomotive, was developed from analyses of freight and passenger locomotives in use in the United States in 1941 and 1946. These analyses indicated that about 75 per cent of the freight locomotives were in the 4,000- to 5,000-horsepower range and had approximately 500,000 pounds on drivers. The studies also showed that approximately 90 per cent of the total locomotives in use in road service handled freight. Consequently, it was decided to concentrate on designing a freight locomotive in this range of power and weight. In order to be attractive and profitable to the railroads, this electric locomotive

Figure 1. Alco-GE gas-turbine electric locomotive ready for service tests on the Union Pacific Railroad

Full text of paper 50-77, "The Alco-GE 4,500-Horsepower Gas-Turbine Electric Locomotive," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Figure 2. Side view and cross sections of locomotive showing "umbrella-type" construction

must show a low initial investment, a low fuel cost, and a low maintenance cost.

MECHANICAL CONSTRUCTION

THE mechanical construction of the locomotive is somewhat unconventional. Instead of the usual truss work in the sides of the locomotive cab, the equivalent mechanical structure is built into the cab underframe. The superstructure, including the roof, hatch covers, and side walls, is supported on vertical uprights from this main underframe in an "umbrella-type" construction, as illustrated in Figure 2. This design was developed because of the necessity for carrying relatively large amounts of fuel and for keeping this fuel below the level of the power plant and generating equipment. In order to obtain an adequate "cruising range," it was necessary to provide fuel oil in proportion to the horsepower rating of the power plant. For the present locomotive, this requires storage space for approximately 6,500 gallons of fuel. Such a quantity is much larger than can be carried in a conventional manner between the trucks and, consequently, the fuel storage tanks are built into the main underframe structure of the cab.

The trucks are of the conventional 2-axle swing-bolster type, as indicated in Figure 3. Each pair of trucks is connected by a span bolster which, in addition to spanning the two trucks and supporting the locomotive cab, also acts as a traction-motor air duct. This arrangement gives a high degree of flexibility on curves. It also has sufficient vertical flexibility to give satisfactory riding qualities even on comparatively rough track. Resonant vibration between the truck equalizers and the swing bolsters was encountered at low speeds. Damping means were provided in the spring system and no further trouble of this type has been encountered.

THE POWER PLANT

THE power plant, Figure 4, is the simplest type of gas-turbine power plant having the compressor and turbine rotors essentially on the same shaft. It is of the "straight-through" type of construction. Air entering the inlet at the left goes through the compressor, where the pressure is raised to approximately five atmospheres gauge; it then enters the combustion chambers where fuel is admitted and burned. The products of combustion pass through the two turbine stages where the available energy is transformed into mechanical energy, and through the exhaust ducts to the roof discharge. No heat exchangers or intercoolers are used. The power-plant governor, fuel pumps, and so forth, are mechanically driven from the shaft extension on the inlet end. The power output is taken off through a shaft extension which is located on the exhaust end of this type of machine.

The electric transmission consists of four d-c traction generators driven by the power plant through a reduction gear. This power is absorbed in eight traction motors, each pair of traction motors being connected to a single generator with no electric interconnections. Auxiliary power is furnished by a d-c generator driven directly from one of the traction generators. This supplies the necessary power for the auxiliaries which are used in starting. The balance of the auxiliary power is furnished by an alternator direct-connected to another of the traction generators. Such auxiliaries as traction-motor blowers, water circulating pumps, cooling fans, and amplidyne exciters receive power directly from this source.

The power plant is started by a diesel-engine-driven gener-

Figure 3. Running gear showing span bolster and two swivel trucks

ator set which is connected across one of the traction generators serving as a motor to crank the power plant up to the firing speed and to assist in further acceleration to a speed where the power plant is self-supporting. Necessary fuel heating, cab heating, and the like, is accomplished by a vapor car-heating boiler. The heating system and boiler are operated on a closed cycle so that storage space need be provided only for the necessary makeup water.

The relative location of various pieces of apparatus is shown in Figure 5. The nose compartments of the locomotive are taken up with train control and air brake equipment. The operating cabs are quite conventional and follow closely the pattern set by the diesel-electric locomotives. Necessary transmission and auxiliary control are located in the two control cabinets just back of the operating cab at each end. The diesel engine with its generator and the heating boiler are shown adjacent to the right control cabinet. Following these, to the left, is the train air compressor and above it the radiators for cooling the lubricating oil. In the center is shown the gear unit with its four traction generators, the two auxiliary generators, and a connection through the alternator for driving the train air compressor. At the left in the equipment cab is the main power plant and the second control cabinet.

Figure 6 shows a typical cross section through the locomotive. It is of interest in that it shows the location of the main fuel tank, air inlet louvers, and, particularly, the bus bars and control wiring above the aisles. All piping is located beneath the aisle floors or beneath the main fuel tank—which calls for a rather unusual treatment of the sand boxes since they must be below the bus bar and control wiring locations.

This location of the electric connections was designed to keep them dry and has proved quite effective even though snow and water are drawn through the air inlet louvers into the cab. It is also quite effective in keeping cleaning compounds that may be used in the locomotive from coming into direct contact with the wiring and deteriorating the insulation.

The control requirements on the locomotive are essentially the same as the requirements for any internally-powered locomotive. The control, at least from the engine-

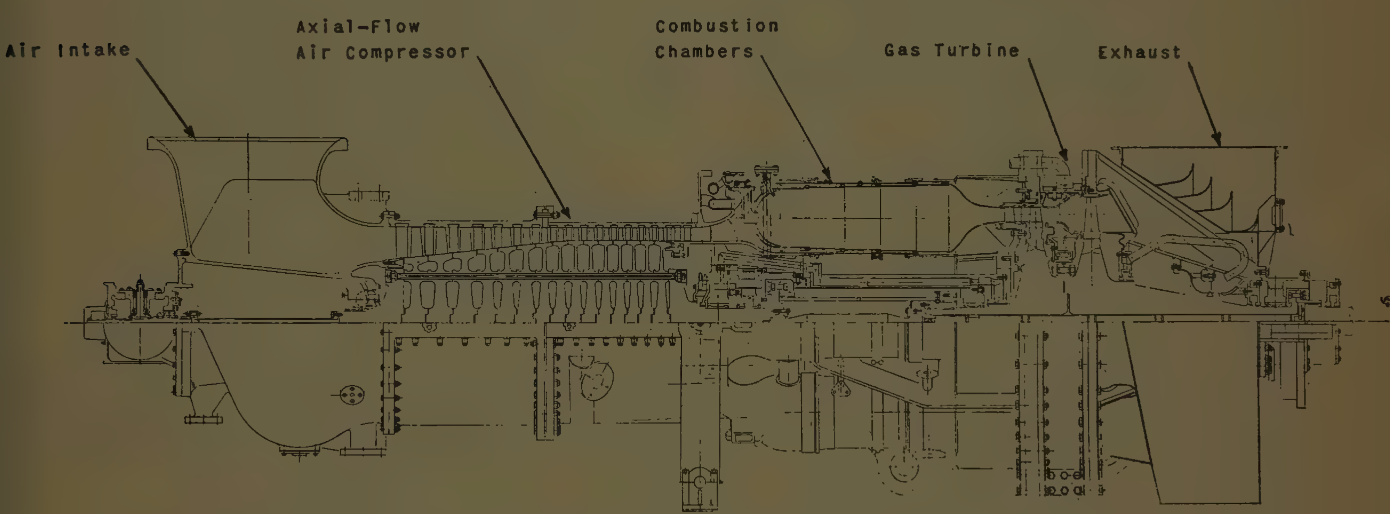

Figure 4. Longitudinal section of gas turbine

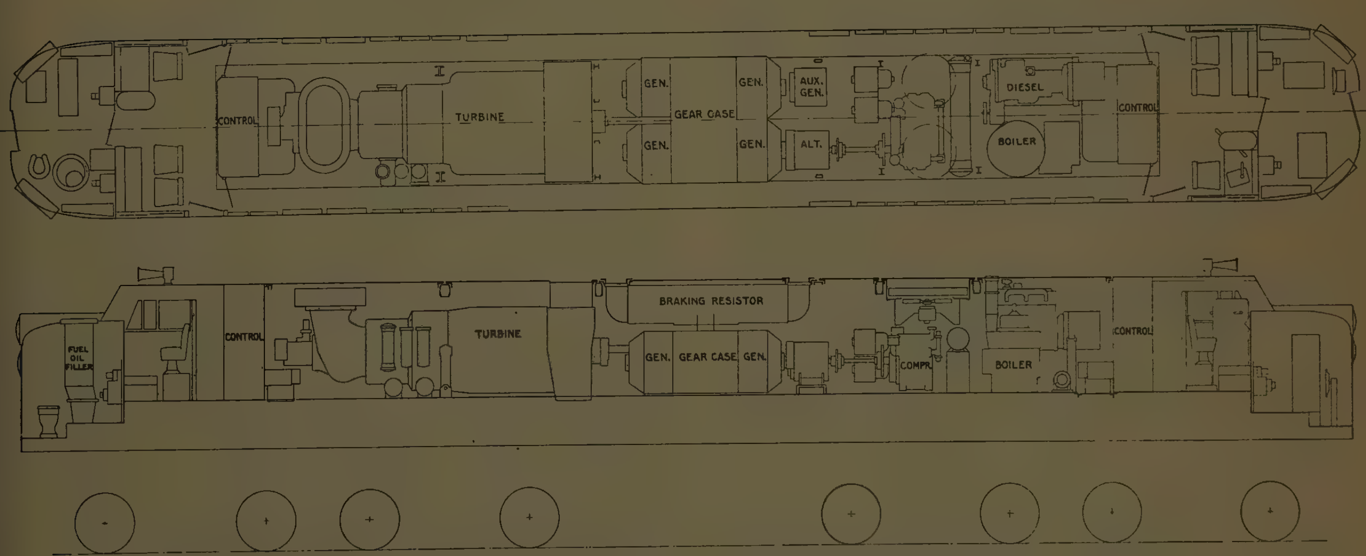

Figure 5. Layout of apparatus in the locomotive

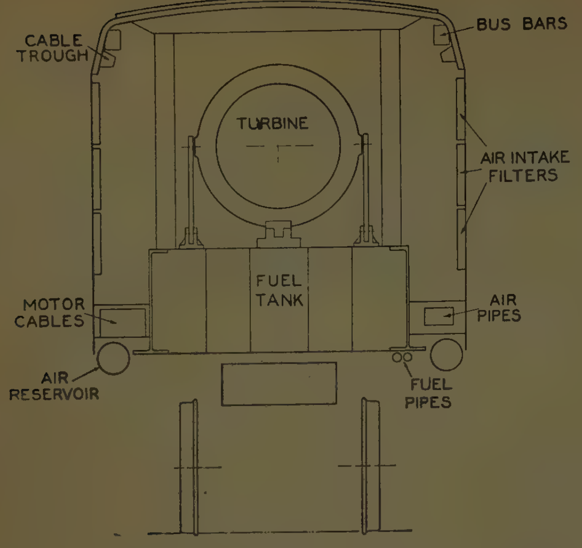

Figure 6. Cross section of locomotive cab showing location of electric wiring and piping

man's point of view, must be simple. It must give adequate control of tractive effort for safe and satisfactory train handling. It must also provide the necessary safeguards against such important factors as locomotive overspeed, low or high lubricating oil pressure, overspeed, or excessive temperature on equipment.

Automatic motor transition and field shunting, operating as a function of locomotive speed, are provided. The dynamic braking control is the same as that used on diesel-electric locomotives, with the energy dissipated in resistors. In short, since the diesel-electric locomotive has become the standard of comparison for new motive power, the same pattern of control was followed.

This locomotive is handled in essentially the same manner as the diesel electric. It differs in only one feature, namely, the rate at which the controller can be advanced from notch to notch, which is lower than the rate on the diesel-electric locomotive. The power plant, with its connected load, has considerably more inertia than the diesel-electric power plants on present-day locomotives and, consequently, its rate of acceleration is lower. A notching guide is provided on the instrument panel at the engineman's position to aid in advancing the controller on this locomotive at a proper rate. This guide will indicate, at a glance, whether the engineman is moving the controller handle too rapidly. Although the proper rate is lower than that to which the enginemen are accustomed, no difficulty has been experienced in starting or handling trains. The reapplication of power after shutoffs proved to be too slow for starting trains. A switch has been installed on the instrument panel which will hold the power plant at full speed under these conditions and permit rapid reapplication of power.

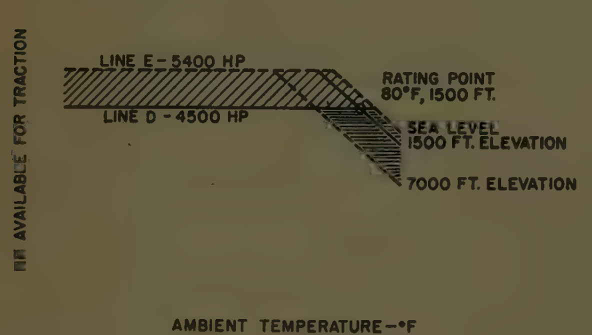

Figure 7. Chart of typical gas-turbine electric drive performance

LOCOMOTIVE CHARACTERISTICS

The locomotive characteristics are, of course, the characteristics of any internally-powered, electrically-propelled locomotive as far as speed and tractive effort are concerned. The capacity of this type of power plant varies with changes in ambient temperature and elevation. The engineman, however, only sees a change in the power which he can obtain from the locomotive.

Locomotive control permits full utilization of available power, up to maximum capacity of the drive (line *E*, Figure 7). Somewhat unconventional speed-tractive effort characteristics result, as shown in Figure 8. The dotted line denotes the usual constant horsepower characteristic (line *D* of Figure 7), while the solid line corresponds to maximum power conditions (line *E*, Figure 7). Speed-tractive effort characteristics in the cross-hatched area between the dotted and solid lines in Figure 8 will be realized when the locomotive is operating under the conditions corresponding to the cross-hatched section of Figure 7. These areas represent extra power available due to the particular characteristics of the gas turbine.

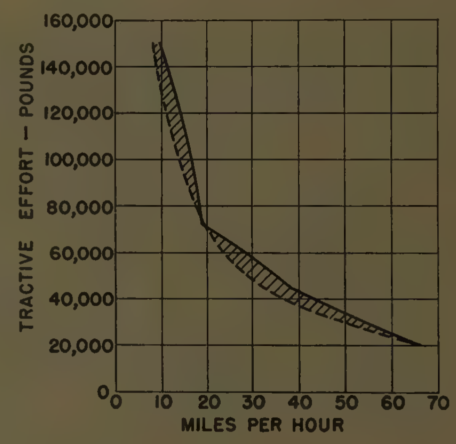

Figure 8. Locomotive speed-tractive effort curve

Installing power-plant capacity to utilize fully all of the capacity in the electric drive is entirely a question of economics. In the case of the gas-turbine power plant with its low specific weight and space characteristics and its fairly wide variation in output with altitude and ambient temperature, it appears to be good business to make this power available in the form of tractive effort whenever the power plant is capable of developing it. This is especially true since the restriction of the output to the conventional constant horsepower would entail the operation of the power plant at partial loads, with consequent poorer efficiency as a result, over a fairly large percentage of the plant's normal life.

A Tribute to Oliver Heaviside

OLIVER E. BUCKLEY
FELLOW AIEE

THE INFLUENCE of great thinkers does not stop at national boundaries. Their message is to the world, and it is fitting that the world pay tribute to them and to the nations from which they come.

The world-wide range of Heaviside's influence upon the science and art of electrical communication is especially clear. He emphasized the role of metallic circuits as guides, rather than conductors, of alternating currents. He developed in complete form the differential equations which describe the behavior of guided waves. He discussed clearly, and in detail, the causes of line distortion, and suggested various methods of alleviating it. He even invented much of the language which is basic to communication engineering today—words such as inductance, impedance, attenuation. These ideas, and these words, are used the world over.

Heaviside was also a great teacher. He did not, of course, mold thought through personal contact. He had no pupils in this ordinary sense. His influence came from his writings, and because these have been found difficult by men of average ability, both in his age and ours, his direct influence did not extend to great numbers of men. But those who understood him were influenced profoundly.

The Bell System has had its full share of such students. Heaviside's teachings have found wide applications in our contributions to the art of communication.

In the early 1890's, John Stone Stone was one such pupil. A little later came George A. Campbell. He shares with Michael I. Pupin the credit for working out in practical terms one of the things Heaviside suggested, the use of loading coils to reduce line attenuation. Later still came John Carson, who regarded himself as the apostle of Heaviside just as Heaviside had regarded himself as the apostle of Maxwell. Carson's book on "Electric Circuit Theory and the Operational Calculus," in which he recast Heaviside's operational methods as integral equations, is widely used.

I, too, owe a personal debt to Heaviside, for I was one of the many who found inspiration in his work, especially when I was occupied with the development of continuously loaded submarine cable for telegraph and telephone use.

The interest of the Bell System in Heaviside's ideas regarding loading goes back to very early days. As far back as April 1891, John Stone Stone wrote a report in which he refers to "Mr. Heaviside's conditions of nondistortion." In it he computed the amount of inductance which would render the New York–Boston toll line distortionless, and stated that the object of the report was "to show the desirability of experimenting with this artificial inductance along the line." This was before Heaviside's own ideas regarding continuous loading had reached their final form.

From this time on, loading continued to be the subject of numerous reports and investigations. At the start the interest centered, at least on Stone's part, principally in the possibility of achieving continuous loading by the use of bimetallic wire. The nature of the problem was only partially understood, so that there were many false starts and unworkable suggestions, but by the spring of 1894, Stone had carried out computations which clearly showed the ineffectiveness of the kind of bimetallic wire originally conceived, and in a memorandum of May 21, 1894, he proposed a form of conductor which revealed a clear understanding of the problem. Meanwhile, in November 1893, Heaviside published his final, and most lucid, paper on loading in which the problem of the bimetallic wire was squarely and clearly dealt with. Undoubtedly this paper was an important factor in developing Stone's understanding of the subject.

I have been at pains to quote these dates because they lead to an interesting speculation. We know that Heaviside's brother visited with telephone men in America in 1893. We also know that Heaviside wrote an appreciative letter to Stone in 1894. Is it possible that a report of Stone's activities reached Heaviside through his brother, and that he was so encouraged by this evidence of active interest in his ideas that he returned to the subject with special vigor? Or was the subject discussed in earlier correspondence between Heaviside and Stone? The letters are not available, so we do not know.

A few years later, Heaviside's vision of the loaded line became a reality; not, so far as land lines are concerned, in the continuously loaded form to which Stone had devoted most of his attention, but by the insertion of coils at intervals as worked out independently by Campbell and Pupin. It was one of the great milestones of telephony. In fact, by about 1920 loading had been installed on more than 300,000 circuit miles of long-distance telephone lines in America. With carrier telephony, the need for loading on long-distance circuits has decreased; however, by 1949 some 20,000,000 loading coils had been installed on Bell circuits.

Continuous loading has also been of great interest to the Bell System, especially in the use of permalloy to make possible a great advance in submarine cable telegraphy.

To emphasize the esteem in which Heaviside was held in our early days, I should like to quote from a letter written in 1894 by the President of the American Telephone and Telegraph Company. Referring to the book "Electro Magnetic Theory," he wrote: "It is a good book all the way through . . ., the way in which Mr. Heaviside brings his propositions forward and states them, and the reasons he gives for them. show that he has brought great patience and intelligence to bear on the subject."

Time has only served to enhance the esteem in which Heaviside was then held, and to justify the many hours of patient study which have been devoted to his writings by succeeding generations of our engineers.

A shorter tribute was presented in a recording by Dr. Buckley at the Heaviside Commemorative Meeting held in London on May 18 by the Institution of Electrical Engineers.
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Pumped Storage Installation in Texas

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MEMBER AIEE

AN INSTALLATION capable of generating hydroelectric power and energy during peak hours and of restoring the water by pump operation during off-peak hours was placed in service at Buchanan Dam, Tex., during 1950. Power and energy are generated by a hydroelectric unit which is similar to modern hydro power plants. The process of lifting large quantities of water from one elevation to another by means of high-efficiency centrifugal pumps driven by electric motors uses the same principles whether intended for domestic, irrigation, or pumped storage use.

Various engineering and economic factors were very important in the selection of this type of installation, and since it is believed that within a few years a number of other locations in the United States will be found to be feasible for this type of installation, a general discussion of these factors are included with the special design features.

Confronted with the problem of adding generating capacity within a limited time, a study of the service requirements was made based on past operating records and future load forecasts. The study revealed that during the maximum load season, the anticipated requirement of the top 14,000 kw of generating capacity would be required only four hours per day during the work week. Sufficient steam energy would be available on such days to operate a pump approximately eight hours as shown in Figure 1. Curves for Sundays and minimum-load season indicated that more than sufficient steam energy was available to fulfill pumped storage requirements. With this factual data, consideration was given to the various types of generating equipment, and the pumped storage hydroelectric installation was selected.

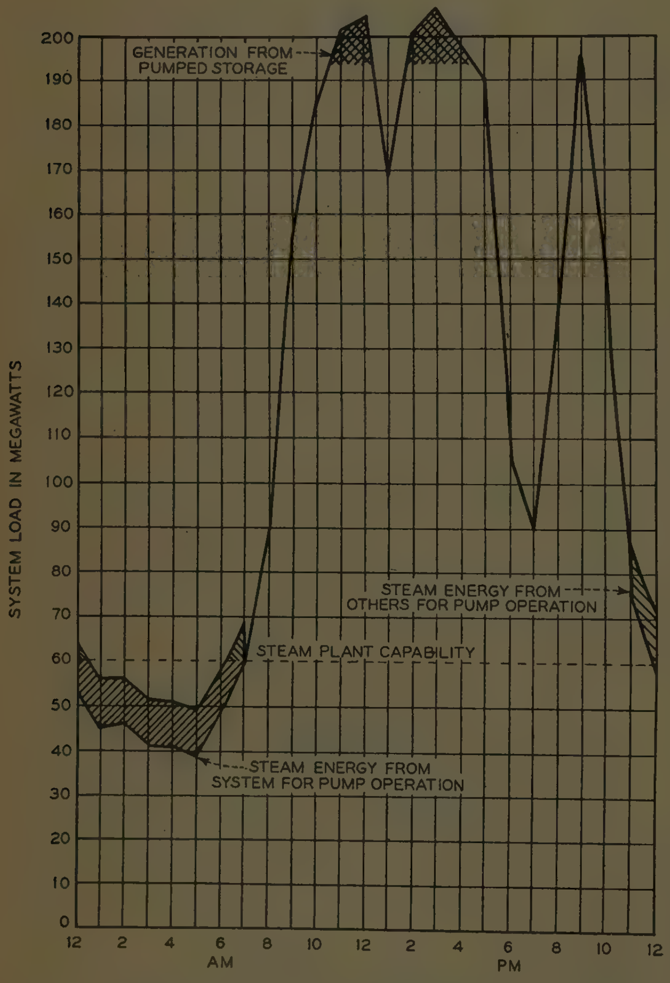

Figure 1. Pumped storage and generating unit operations superimposed on typical weekday load curve

Water is released from Buchanan Lake through the turbines during peak hours. This water flows into Inks Lake where a portion is used to operate the Inks plant. During off-peak hours electricity generated by steam plants is used to pump water from Inks Lake into Buchanan Lake to assure an abundant supply of water for on-peak operation. Approximately six hours of operation of the generating unit is obtained from the water that is pumped during every nine hours of pump operation.

The turbine and 14,000-kw generator unit are of standard design except that a separate exciter is used to permit synchronous starting of generator and motor. The 804-cubic-feet-per-second pump operating against a 120-foot head will be driven by a 13,450-horsepower 80-per cent-power-factor-leading 164-rpm 6,900-volt vertical 2-bearing synchronous motor. A motor-operated butterfly valve is installed between the pump and penstock. The over-all efficiency of generator-pump installation exceeds 69 per cent.

The motor is started manually by connecting the armature circuits of the generator and motor and then applying full field to both units. The two units are started from rest by means of torque applied to generator shaft which, in this instance, is water going through the turbine. The motor is accelerated to normal speed by the synchronous torque developed. All of this is done with the butterfly valve closed and the water depressed. After the generator and motor have been brought to synchronous speed, the two units are synchronized with the remainder of the system and load applied to the motor by allowing the water to enter the intake side of the pump and then opening the butterfly valve. The generator used to start the motor is then shut down, and the power and energy requirements of the motor are supplied from steam generating sources.

Steam plant efficiency may be improved by proper correlation of operations in an interconnected system having pumped storage units. Increased loads on steam plants during off-peak hours will improve load factors where sufficient off-peak energy is available for pump operation.

Digest of paper 49-126, "Pumped Storage Installation," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE South West District Meeting, Dallas, Tex., April 19–21, 1949. Not scheduled for publication in AIEE *Transactions*.

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Responsibilities of a Consulting Engineer

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The basic responsibility of the consulting engineer, in common with all engineers, is that of exemplary citizenship, service to mankind, and sound thinking in relation to the problems of the times. In addition, when called upon to apply his technical knowledge and experience in his own particular segment of the engineering field, he must do so with vision, understanding, and professional integrity.

IN CONSIDERING the responsibilities of the consulting engineer, we need first to examine those responsibilities that are the basic obligations of every engineer regardless of whether he may be in that relatively small segment of the profession engaged in consulting practice or whether he may be one of that larger group engaged directly in industry, commerce, research, teaching, government, or the like. After these basic obligations are well understood, we can consider those additional responsibilities that are imposed upon the consulting engineer, particularly those which arise in the consulting engineer's relationship to management.

In this self-examination, we should ask ourselves whether our young profession is growing up to its responsibilities. Are we, as individual engineers, maturing? Are we taking a broad viewpoint of the problems of mankind? Are we giving our fellowmen the full and complete advantage of our special training and qualifications, or are we sidestepping important responsibilities? Are we vocal, or do we allow matters that should be our concern to fall by default to the incompetent and immature, who cannot cope with them but who, unfortunately, can gain great authority and the power of decision over them? Beyond this we need ask ourselves if we are being exemplary citizens. Do we instinctively respect the rights and privileges of others?

QUALIFICATIONS AS CITIZENS

LET us begin by taking a candid look at our qualifications. Is it not part and parcel of our very nature to think in terms of the fundamental, in the basic concepts of time and space, cause and effect, of sound economics? Are we not intimately familiar with the laboring man's problem, and do we not know him in his working environment? We work with management; we worry with management; we see and understand the big and small problems facing management and all industry. Costs are continuously and indelibly in our minds. We daily face the challenging problems of competition, yet must remain professional in our approach.

We, as engineers, have the vision to see the total dangers of the share-the-wealth philosophy, the nationalization of industry. We probably realize, too, better than any other group the great technological opportunities that lie ahead for the benefit of mankind. We know hard work; we know cold facts; we are realists. We have a full appreciation of the importance of private initiative, and understand well the triumphs of man when free to use his own resourcefulness. State or national borders do not define our field of work; in fact, it extends the world around. No other profession, no other group can equal that of the engineer in richness of background, maturity of experience, or potential ability to serve mankind in this larger way. No other group is more capable of keeping its feet on the ground in approaching the basic problems of our times.

Most engineers are fundamentally honest and sincere, and have done a good technical job in designing structures and in making them inherently safe. For these qualities we have merited and received the respect of our fellowmen. As a profession, however, we are as yet in adolescent life. We have not merited nor have we received the respect of others for the satisfactory discharge of our broader responsibilities, for, unfortunately, a count of noses finds Mr. Engineer not represented in proportion to his potential strength on neighborhood civic committees nor in the thousand and one other activities of city, state, and nation.

In addition to our expertness in technical matters and our fundamental adherence to the sacred canon that the design must be safe, more of us must participate in broader activities. This does not imply that we need to become politicians, but we must have the courage to challenge the warped and impractical ideas of the demagogue, to oppose those who think that by pressing a button, filling out a form, socializing industry, men can live in some Utopian existence conjured up by a regimenting state. We must challenge those who indulge in loose or slippery talk and present fallacious data to gain their objective. In short, as engineers we must take full advantage of our unique opportunity to rebuild the importance of man himself as an individual. In every way we should act as a motivating influence, and thus we can add much needed stability to society as a whole.

We, as engineers, need to join with those relatively few members of our profession who are already performing outstanding work in the humanities and thus are experiencing that fullness of satisfaction which comes from doing for others. We need to develop a fuller understanding of the great fundamental changes that have occurred within our lifetime, of the draining of our natural resources, and the alarming dependence of the average man upon scientific

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Full text of a conference paper presented at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950.

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and engineering miracles to solve all problems and do all work. We need to help those who are struggling with the basic problems of our nation's welfare and those leaders of our profession who are urging that we take stock of our nation's resources and plan well for the future. In reference to this subject, Dr. Warren K. Lewis, Professor Emeritus of Chemical Engineering at the Massachusetts Institute of Technology, has stated that if all coal- and oil-fired steam locomotives were changed to diesel operation, the total oil requirements for the resulting diesel operation would be less than the amount of oil now used by the railroads for diesel plus oil-fired steam locomotives; the railroads of the United States then would use but two per cent of the nation's annual fuel requirements rather than 12 per cent as at present. Also, according to Dr. Lewis, the annual fuel equivalent value of our present hydroelectric production is but three per cent of total fuel requirements. One may well wonder if the average citizen realizes this relationship or if he has not acquired, through pressure politics, a much exaggerated concept of the importance of water power.

THE PROBLEM OF ORGANIZATION

It would be well if we as individuals were more articulate in our daily business and social lives; it would be well if we were more articulate as a profession. It is here, of course, that we as a profession face a challenging problem of our own—that of searching for and finding an organizational mechanism which will permit our profession to carry out the broader phases of its yet adolescent life. No profession can be articulate unless it is representative; it cannot be representative unless it is responsible. In this search for representation we need to deliberate fully, plan carefully, and act wisely lest our real aims and purposes be defeated and our profession constrained from reaching full maturity.

The possibility of a narrowing rather than a broadening of our professional life should be of genuine concern to every one of us. We have only to look at the rise of certain state barriers discriminating against out-of-state residents, and in other ways restricting the normal practice of engineering, to see the result of immature and selfish thinking. We must be ever vigilant lest our profession, which should be almost as universal as mathematics itself, becomes caught in a web of sectionalism or shortsightedness. Shallow principles have no place in the engineering profession, and must be checked. The freedom and opportunity of our profession to serve industry, our fellowmen, and society must not be stifled by a selfish minority within our own ranks acting in concert with small caliber, "stateistic-minded" politicians.

Neither the legal profession, which by necessity must operate within areas of political jurisdiction, nor the medical profession, can offer us a ready pattern. Ours is a different profession; we have different problems; we have different situations; we have different responsibilities. We must develop our own professional organization and specific codes of practice. However, we do have in common with these other professions the concept of a professional man that requires practice with technical expertness, the highest ideals of honesty and integrity, and exemplary citizenship.

Until we find a solution to our organizational problem, it seems increasingly clear that it is the present responsibility of each of us to support both our technical and professional societies unselfishly and give them the benefit of our best judgment. Only by supporting and having a voice in both of these phases of our professional life can each of us be assured that the final solution of our problem will be satisfactory, mature, and lasting. Perhaps we should add parenthetically that the engineer's personal expenditures for membership in technical and professional society activities should be placed in the "must" column of his family budget. These are relatively small for the light, heat, and shelter of his professional life. We need to remind ourselves that voluntary groups are vital institutions through which man grows and serves others. For the engineer, his technical and professional society activities provide a most important medium for exchange of ideas. Here is where satisfactory answers must be found to many challenges facing our profession; for instance, the increasing problem of the young engineer now being graduated at the rate of approximately 45,000 per year as compared with some 5,500 in the medical profession. This is a graduating ratio of 8 to 1 as compared with a practicing ratio of about 2 to 1.

The fundamental responsibilities just discussed as applying to all engineers provide the very foundation upon which a consulting practice must be based. For a consultant above all must be a professional man serving himself only to the extent that he serves others first. To borrow a term from the psychologist, we may say the consultant must be an empathic man, which, in the language of psychology, is a man who imaginatively projects his own consciousness into an object or person outside himself. This essentially is what the consulting engineer is called upon to do in every assignment. Before he can give his best advice or counsel, he must thoroughly understand not only the engineering–economic problems confronting the client, but the client's own situation as well. Then, having understood, he must protect his client with strict professional confidence. As a professional man, he cannot engage in fee or price competition with his fellow consultants. On the other hand, it is his basic responsibility to so conduct himself that the cost of his services to his client is kept to the minimum consistent with the best final over-all result.

THE CONSULTING ENGINEER

It will be helpful in enumerating the more important specific responsibilities of the consulting engineer to review briefly the types of service he is usually called upon to perform. For convenience, these various types of service may be roughly classified in the following five broad categories:

1. Project work that, generally speaking, includes all or any part of the engineering work associated with a prospective or actual construction job (preliminary investigations and studies; design, specifications, and drawings;

contracts; construction supervision, job costs, and inventory records; initial operation, test runs, and final acceptance).

2. Process or equipment design work, which often may involve research and development, patents, trade secrets, classified government material or work, and the like.

3. Professional services as a consultant, often to review operation procedures, a plan or project, or to assist a client directly within the framework of his own organization.

4. Professional services as an expert witness in legal and labor matters, rate cases, hearings, appraisal and valuation work.

5. Professional services as an adviser to an investment house, insurance company, institution, or governmental authority.

Project work may begin with, or consist entirely of, a preliminary engineering survey or study. Such a study must be approached by the consultant with an open mind. It is here he must visualize the whole problem, evaluate the over-all concept, and reach a fundamental understanding of his client's situation. The consultant must set a realistic period of time for the accomplishment of the study—allowing thoughtful and deliberate consideration commensurate with the problem at hand. If the assigned area under investigation proves too narrow for reaching a satisfactory solution, this he must make known to his client. Experience, plus the exercise of judgment and reasoning, must then lead the consultant to select from many possible combinations those arrangements or plans appearing to have merit. He must then study these selections in detail to understand or compare the similarity or differences between them, their relationships in time and space, and to be able to separate the trivial from the significant.

A comparison of engineering alternatives often involves painstaking chores; these the consultant must willingly accept as a basic part of his responsibility in developing the final solution. Usually in this work of selecting an engineering alternative, the consultant finds that an analysis of the incremental return on each incremental investment helps clarify an otherwise obscure differentiation.

Engineering judgment frequently plays a very important part in selection, but it is the consultant's responsibility to narrow to the minimum that area in which judgment must be applied. This should be done by examining the problem under limiting conditions and by applying other tested criteria. Likewise, the human element in the problem and performance under future business conditions must be appraised in as thorough a manner as possible. The consultant must understand the nature and extent of calculated risks and fully explain them to his client. The duration, as well as degree, of exposure to various conditions must be well understood.

The consultant must have the honesty and courage to make recommendations as indicated by the results of his study, regardless of opinions held by others. At the same time, he must never violate the canon of professional ethics regarding the passing of judgment upon the work of a fellow engineer. If he is to avoid the embarrassing situations that can arise out of these seemingly contradictory mandates, it will be necessary for him to hew to the strictest professional principles. Above all, the consultant must never be motivated by personal interest in recommending a project that has questionable merit or which the client could better delay until a more propitious time. Frequently, of course, preliminary study work establishes the very character of the final design.

Before accepting a project design assignment a consultant must satisfy himself as to his prospective client's reputation, his good intention to carry out the project, and his resources to finance it. In designing, the consultant must have the courage to make a new and bold approach, yet he must neither indulge in creating a monument to himself nor let his pride of original concept or a minimizing of his office cost hold him to an unsatisfactory prototype solution. The consultant must, by application of knowledge and experience, be able to improve upon and perfect the usual structure, formula, circuit, or perhaps an entire industrial process. He thus adds his contribution to the gradual process of achievement by which most of our industrial progress has been made. A consultant must insure that the design will follow the spirit of its fundamental concept and stay within the cost estimate. Should the detail design or field conditions indicate a significant departure from the agreed-upon plan, concept, or cost, the consultant must immediately notify his client and reappraise his plans.

Unless specifically instructed otherwise by the client it is, of course, the basic responsibility of the consultant to develop the most economical plan consistent with legal statutes, the rights and privileges of others, and the welfare of the community. When an otherwise most acceptable plan might be harmful to the community, this must be avoided for the ultimate advantage of the client as well as that of the community.

It is mandatory for the consultant continuously to guard against "gold-plating" and an overly conservative design. To do this, he must clearly distinguish between what is necessary for safety and what areas are subject to economic gains by the taking of calculated risks. In fact, the constant appraisal of calculated risks is a most important responsibility of the consultant. He must subject each arrangement to a searching examination of potential failures, service outages, and the like, and then determine the economic justification for duplication and the erection of various types of safeguards. He must studiously avoid burdening the design with protective features often urgently supported on the basis of some past experience but which are not relevant or important in the case at hand.

An important consideration should be unity of design, with ample flexibility for future expansion or process revisions dictated by changed business conditions.

FURTHER RESPONSIBILITIES

There are, of course, many facets to the consultant's responsibility in project work that cannot be included in this short discussion. However, it seems important to touch briefly upon the relationship of the consultant to the manufacturer and the utilization of standardized designs.

It is the consultant's obligation to maintain an open-door policy toward all reputable manufacturers and to avoid, wherever possible, discrimination in the preparation of specifications. Bids, too, must be received with an open mind and with professional courtesy. A consultant must studiously avoid becoming obligated by accepting from a manufacturer service or technical assistance beyond what is reasonable and proper. Every consultant must be aware of the importance of promoting standardization, yet he must be ever vigilant to detect standardization trends that are primarily and essentially for the benefit of the manufacturer but are a disadvantage to the ultimate user. All standards should be well co-ordinated and integrated with other standards if they are to stand the test of time. For example, the ambient temperature and the temperature rise allowed in switchgear must be co-ordinated with temperatures permitted in the instruments, instrument transformers, cables, and other equipment that are to be located in the same enclosure.

In the field of process or equipment design, the consultant must be prepared and able to supplement, and to implement, the newest discoveries and developments of the scientist so that they may be utilized for the service of mankind. Thus, the engineer is pushing forward the frontiers of both science and engineering. In addition to technical expertness, the consultant has the grave responsibility of safeguarding industrial secrets and classified material bearing on national security.

The consulting engineer who is retained to assist a client within the framework of his own organization or to review a specific plan or proposal has the basic responsibility of providing his client with good sound engineering advice. This must be developed through a fresh, vibrant yet co-operative, approach, a full and mature understanding of the client's situation, and a harmonious association with his responsible personnel.

The dominant responsibility of a consultant when serving as an expert engineering witness or in appraisal and valuation work is more than that of developing and presenting an honest, fair interpretation of the facts according to the law or regulation which applies. It is rather a serious weighing of issues in which professional integrity, the interest of his client, and a fair attitude toward the question at hand must all be reconciled in his conscience.

Many broad and comprehensive problems fall within the scope of an engineer's responsibility when he acts in the capacity of an adviser to an investment house or governmental authority. In such a capacity, the engineer often may wield an important influence in decisions of the greatest magnitude. Frequently he must deal entirely with laymen who hold key posts of government or finance. The engineer in such surroundings must hold fast to his professional principles, fundamental engineering–economic thinking, and the over-all concepts of human dignity.

It might be said in conclusion that the basic responsibility of the consulting engineer, in common with all engineers, is that of exemplary citizenship, service to mankind, and sound thinking in relation to the problems of our times. He must be ready and willing to challenge immature and irrational thinking wherever he encounters it, continually standing for the highest principles of man's welfare and dignity. He must unselfishly give his moral and financial support to his technical and professional society activities—thus assuring to himself and the engineering profession the role of serving mankind in the fullest sense.

The extent to which the consulting engineer in his daily work visualizes and comprehends an engineering–economic problem in its entirety, understands his client's particular situation, has the courage of his own convictions, is fair and honest, and practices his profession with technical expertness is the extent to which he will live up to his obligations to his client and thus to which he will reap the reward of complete satisfaction.

RCA's "Little Giant" Electron Microscope

The Radio Corporation of America has developed a new electron microscope only 30 inches high which is expected to sell for less than $6,000. The new microscope, which uses permanent magnet lenses requiring no stabilization circuits and controls, will provide useful magnifications up to 50,000 diameters by photographic enlargement, with direct magnification in the instrument ranging up to 6,000 diameters. It has a 50,000-volt accelerating potential and is more than 20 times as powerful as the best optical microscope, with a depth of focus 150 times as great. The lower end of the magnification range of the Permanent Magnet Electron Microscope overlaps that of the conventional light or optical microscope, making it possible to progress by stages from the known to the unknown. Convenience and time saving is afforded by an engineering advance which permits insertion of specimens into the evacuated column, and their removal, without breaking the vacuum. In addition, photographic plates may be changed without admitting more than a small amount of air to the column. As a result, pumping time between plates is reduced to only 90 seconds, which is just about enough time for the photographic development normally carried out between exposures. Simplicity is achieved without sacrifice of quality performance by means of a combination of design factors centering around a new electron optical system employing permanent magnet lenses instead of the conventional electromagnetic or electrostatic lenses. Through the use of permanent magnets, unusual stability is permanently achieved and many parts and controls are eliminated.

Tape-to-Page Translator

A. E. FROST
ASSOCIATE AIEE

IN A REPERFORATOR switching telegraph system all messages allowed to enter the system are in the form required for tape printer operation. Certain tie-line patrons' offices are equipped with page teleprinters, which are unsuited to record messages prepared for tape teleprinter reception. The tape-to-page translator permits the extension of switching methods to the delivery of telegrams to patrons' offices equipped with page teleprinters.

Page operation differs from tape operation fundamentally in that page operation requires the transmission of characters for carriage-return and line-feed functions. There are also differences in code assignments of characters involving the equals sign, number sign, per cent sign, paragraph sign, apostrophe, comma, and period. In addition, it is customary to end a page-printer message with a carriage return and a sufficient number of line feeds to provide well-defined separation between messages. Conversions required to account for these differences are performed by the translator. In switching to a page tie-line, a translator is connected between the switching transmitter and the line. Each character is read by the translator and, if no conversion is required, is transmitted as received.

Figure 1 shows a block diagram of the translator components and illustrates the plan chosen to effect translation. Tape teleprinter signals are received and perforated by the reperforator. The perforated tape passes through the tape transmitter, which sets up the code combinations punched in the tape, character by character, on five reading relays. The reading relays carry several sets of contacts for reading the character and an additional set of contacts from which the selection may be transferred to the storing relays, should no translation be required. Associated with the storing relays is a sending distributor for transmitting the signals to a page teleprinter circuit.

Should a character requiring translation be set up on the reading relays, a circuit is established to energize one of the translator relays. One translator relay is required for each of the nine functions and, when operated, it sets up the conditions required for the particular translation. Since most of the conversions require that more characters be transmitted than are received, it is necessary to establish a condition whereby a succession of conversion characters may be transferred, one at a time, to the storing relays. This is the purpose of the transfer relays. Operation of a translator relay immediately causes the operation of an appropriate transfer relay which carries contacts for the transfer of the first conversion character to the storing relays. Provision is made that this transfer shall take place from the transfer relays and not from the reading relays;

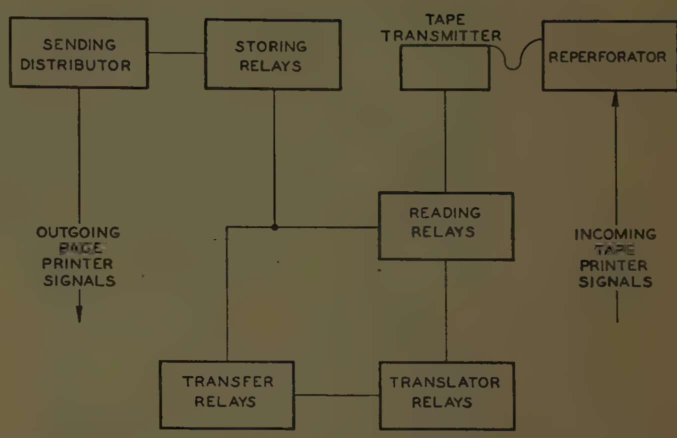

Figure 1. Block diagram of the translator showing the components necessary to permit delivery of tape-printer messages to offices equipped with page teleprinters

that is, the first conversion character is transferred to the storing relays in place of the character requiring translation. Then a second transfer relay is operated and the first one released to effect the transfer of the second character to the storing relays. This process is repeated as many times as is required. The operation of the last transfer relay establishes circuits for the restoration of normal transmission.

It is fundamental that transmission to the translator must be stopped during the transmission of additional conversion characters. The perforated tape furnishes the necessary loose coupling between the originating transmission and the translator. The tape transmitter is stopped and started again by the translator as required.

The translator is provided with two items not shown in this diagram. One is a counter to count the number of characters in each line of page copy to indicate that a carriage return and line feed should be inserted upon the reception of the following word space; the other is a rotary switch used to effect the transfer of the conversion characters for the paragraph sign and also the carriage return and eight line feeds at the end of a message.

The division of the tie-line traffic load between tape teleprinters and page teleprinters averages about half and half. Therefore, only about one-half as many tape-to-page translators are required as there are tie-line transmitters. The translators are installed on a concentrator basis in such a manner that when a transmitter has a message for a page tie-line it will obtain the connection through an idle translator. The request for a translator is wholly automatic and the tie-line operator need not know to which type of teleprinter the message is being transmitted. The output of the translator transmits directly to the page tie-line.

In application, the tape-to-page translator is found very effective in improving efficiency and speed of service.

Digest of paper 50-13, "Tape-to-Page Translator," recommended by the AIEE Committee on Telegraph Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N.Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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A New Dry-Type Insulation for Instrument Transformers

R. A. PFUNTNER R. E. FRANCK F. R. D'ENTREMONT

A new type of instrument transformer insulation, called butyl, can be molded right over transformer core and coils. Tests have shown butyl to be superior electrically, mechanically, and chemically to asphalt-impregnated paper insulation, operating at or below 15,000 volts.

ONE OF the most important functions of instrument transformers is that of insulation. Whether it is a high voltage or a high current that is to be measured, the measurement can be made in a practical manner only if the end device is insulated from the high circuit voltage.

It has been considered good practice to use two types of instrument transformer insulation depending on the circuit voltage. In general, above 15,000 volts, liquid-filled designs have been used, while below this voltage the dry or compound-filled construction has been employed.

A new dry-type insulation, a molded butyl compound, has recently been developed. This new insulation possesses many outstanding advantages over former dry-type insulation. The use of molded butyl insulation on a 5,000-volt indoor current transformer is illustrated in Figure 1.

Present types of dry or compound-filled insulation are:

Dry Type. Present practice of producing dry-type instrument transformers differs somewhat in detail between various manufacturers, but the basic process is essentially the same for all. The coils are wrapped with a fibrous material in the form of tape or sheets so that a given number of layers of insulation cover the entire surface of the coil. This taping is usually applied to the primary, or high-voltage, coil and is sometimes repeated to a lesser degree on the secondary coil. The coils are then assembled together, and the core is placed in position. The complete assembly is then dried out thoroughly and vacuum-impregnated with an insulating compound.

Some manufacturers use crepe paper for wrapping the coils and others use varnished cambric or other similar materials. Asphalt compound or varnish usually is used as the impregnating medium.

Compound Filled. Compound-filled transformers are insulated in much the same manner as dry types, except that a metal and porcelain casing is placed around the core and coils, and the treatment with insulating compound is done in this casing. As a result, the casing is entirely filled with compound.

Figure 1. General Electric type JKM-3 butyl-molded 5,000-volt instrument current transformer

This is the first instrument transformer placed in production using butyl insulation

Figure 2. Assembled core, windings, and base of type JKM-3 instrument current transformer before molding with butyl

Primary coils are assembled over secondary and core, providing adequate clearance between parts for butyl insulation

NEW MOLDED BUTYL INSULATION

THE new butyl insulation is placed around the coils of the transformer by a molding process. The core and coils are assembled together without previously being wrapped with any insulating material. In the current-transformer design illustrated in Figure 1, the secondary coils are mounted on the legs of the core. The primary coils are assembled over the secondary and core with adequate clearance between parts to provide space for the butyl insulation. This assembly is illustrated in Figure 2.

The assembly is then placed in the mold which has an internal cavity that will form the outside contour of the transformer. The proper relationship between parts is determined by the mold, which supports the components in such a manner as to provide continuous and homogeneous insulation throughout the transformer. Butyl compound is then injected into the mold under controlled pressure and temperature conditions. After curing for the proper time and at the specified temperature, the completely insulated transformer is removed from the mold.

Essentially full text of paper 50-66, "A New Dry-Type Insulation for Instrument Transformers," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950.

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Both the new process for insulating instrument transformers, and the butyl compound used in the process, have distinct advantages over former types of hand-taped and impregnated forms of insulation. The molding process assures machine precision of dimensions, as well as producing a 1-piece homogeneous insulation which completely surrounds the high-voltage winding, fills all the spaces between the windings and the core, and forms a protective coating over the outside of the transformer. Molding also provides a ready means of obtaining an attractive appearance in the finished product.

The special butyl compound used in the process has excellent dielectric properties over a wide range of temperature and humidity, and will withstand many abnormal operating conditions without serious deterioration. It is tough and resilient so that it will withstand the mechanical shocks of high overloads and accidental rough handling without damage to the transformer.

DESCRIPTION OF TRANSFORMER BUTYL COMPOUND

Butyl is a synthetic rubberlike material developed just prior to, and during the war. One major application for this material at the present time is for automobile inner tubes, since butyl holds air extremely well. Another application is for cable insulation, a special compound with excellent electrical properties having been developed for this purpose. The basic gum used in cable butyl is compounded with slightly different fillers to make transformer insulation.

The basic gum is a copolymer of polyisobutylene and isoprene, both derived from petroleum. Polyisobutylene is a gum-like material made up of carbon and hydrogen atoms so joined together as to be relatively inactive chemically. As such, it cannot be vulcanized with sulphur or other agents to change the soft gum into a rubber-like product. However, by the addition of one to three per cent of isoprene, which is vulcanizable, the entire mixture can be vulcanized to impart to it many of the excellent physical properties of natural rubber, without the relative chemical instability of this material.

To understand the chemistry of butyl, let us compare it with that of natural rubber. Natural rubber is also a gum-like material composed of carbon and hydrogen atoms. As represented in Figure 3, these are joined together chemically by valence bonds or links, hydrogen requiring one link to be chemically combined, and carbon requiring four. In natural rubber, the ratio of carbon to hydrogen atoms is five to eight, and these are arranged as shown, in long chains forming very large molecules.

As is illustrated, hydrogen is joined with single links while four links must radiate from each carbon atom. However, there are not enough hydrogen atoms in natural rubber, so two carbons are double linked together. This is a relatively unstable condition, and the addition of another element, such as sulphur, destroys the double link which for the purposes of this discussion is shown in simplified schematic form in Figure 3. This chemical change vulcanizes the rubber. As is illustrated, not all of the double links need to be stabilized by sulphur atoms to get proper vulcanization. In fact, if enough sulphur were added to combine completely with all the unstable carbon atoms, hard rubber

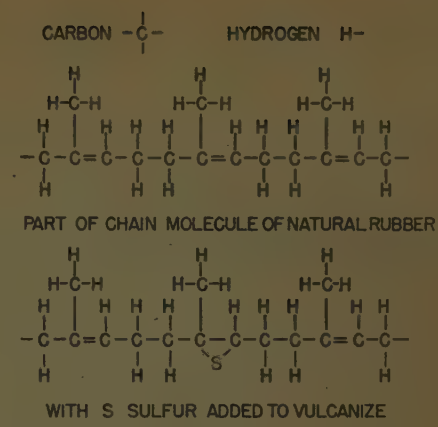

Figure 3. Structural representation of a natural rubber molecule

Hydrogen is joined with single links while carbon is connected to molecule with four. Above, some carbon atoms have double links, a relatively unstable condition. Below, in vulcanization process, sulphur destroys double link

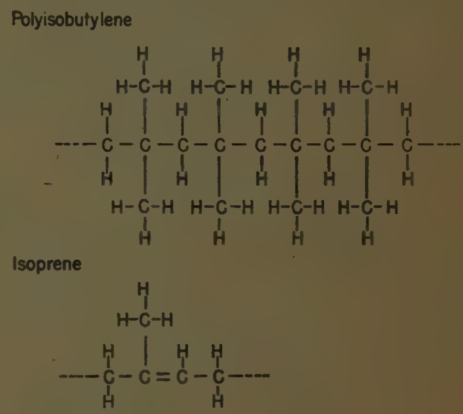

Figure 4. Structural representation of butyl compound

Polyisobutylene, which comprises 97 to 99 per cent of butyl, has no double links, giving chemical stability. Double links in the one to three per cent isoprene present permit vulcanization

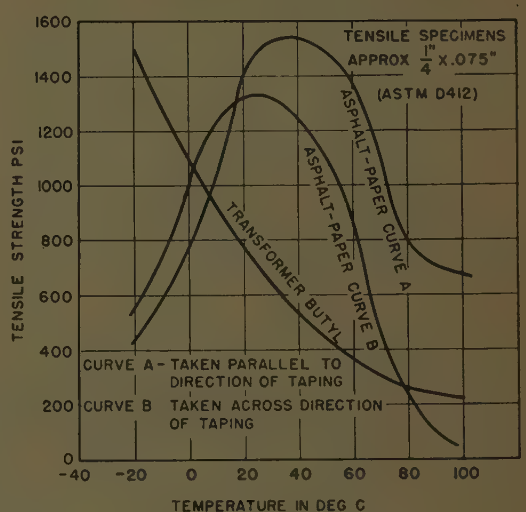

Figure 5. Tensile strength versus temperature in transformer butyl and asphalt paper

such as was once used on telephone receivers would result. Consequently, even vulcanized rubber is relatively unstable, and the addition of other elements such as oxygen or ozone will break up the remaining double links. In this case, ozone plus water vapor breaks the structure apart and destroys the rubber properties. Cracking and hardening, usually found in old rubber, are characteristic of this destruction.

Butyl gum does not have this instability. Polyisobutylene, which comprises 97 to 99 per cent of the gum, has no double links, as is illustrated in Figure 4. The one to three per cent of isoprene, also illustrated in this figure, has the

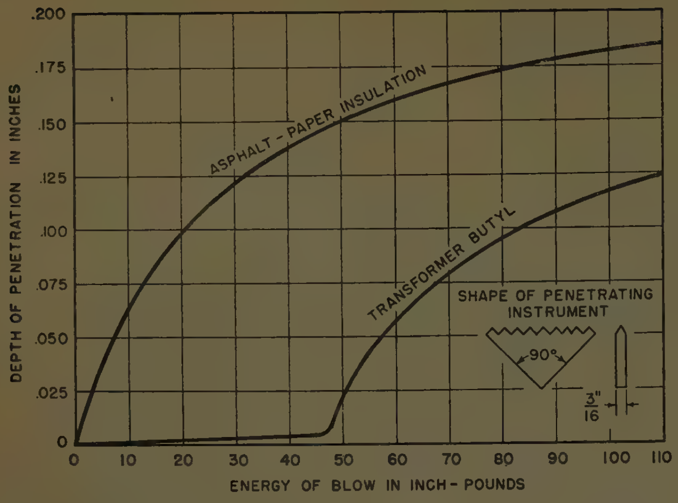

Figure 6. Resistance to mechanical damage in transformer butyl and asphalt paper

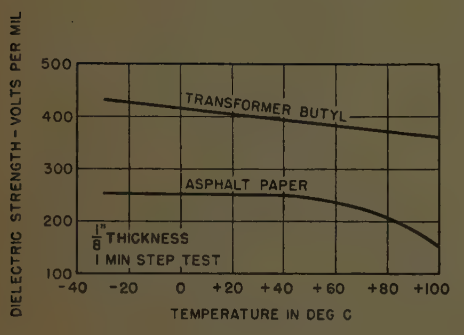

Figure 7. Dielectric strength (60 cycle) versus temperature in transformer butyl and asphalt paper

Table I. Physical Properties of Transformer Butyl and Asphalt Paper Room Temperature

Property	Transformer Butyl	Asphalt Paper
Tensile strength (American Society for Testing Materials D412, pounds per square inch)	700	1,300
Elongation (ASTM D412)	680 per cent	10–30 per cent
Hardness (shore "A")	50	90
Elasticity (shore)	38	—
Abrasion resistance	Satisfactory	Satisfactory
Flexing resistance	Excellent	Poor
Cutting resistance	Satisfactory	Satisfactory
Tear resistance	Satisfactory	Satisfactory
Resistance to mechanical damage	Excellent	Good
Specific gravity	1.3	1.1
Water absorption, per cent*	7	30
Specific heat	0.36	0.39
Thermal conductivity (calories per second per cubic centimeter per degree centigrade	6.45×10^{-4}	5.02×10^{-4}

* Per cent weight increase after one week immersion in water at 70 degrees centigrade.

Table II. Chemical Properties of Transformer Butyl and Asphalt Paper Room Temperature

Property	Transformer Butyl	Asphalt Paper
Corona resistance	Good	Good
Ozone resistance	Good	Good
Sunlight resistance	Good	Good
Flame resistance	Good	Poor
Resistance to attack by:		
Toluene	Poor	Very poor
Carbon tetrachloride	Poor	Very poor
Transil oil	Fair	Poor
Sulphuric acid (30 per cent solution)	Good	Fair
Sulphuric acid (3 per cent solution)	Good	Fair
Sodium hydroxide (10 per cent solution)	Good	Poor
Sodium hydroxide (1 per cent solution)	Good	Fair

same double links as found in natural rubber. However, practically all of these extra valence bonds are used up in the vulcanization process, so that a remarkably stable material results.

To use butyl gum for insulation, it must be mixed or compounded with suitable fillers to give it increased hardness and with a small amount of sulphur and other similar agents to provide for vulcanization. This compounding changes the sticky translucent gum to the opaque vulcanizable material used in the molding of transformers. The vulcanizing process, which produces the tough flexible insulation of the final product, occurs during the cure, after the butyl has been completely injected into the mold and around the other parts of the transformer.

CHARACTERISTICS OF BUTYL INSULATION

Before butyl insulation could be used for instrument transformers, its properties had to be evaluated in terms of all the various conditions such insulation is required to meet. These characteristics were determined primarily by laboratory test.

Since the first instrument transformer placed in production using butyl insulation was the 5,000-volt indoor current transformer illustrated in Figure 1, the over-all performance of butyl was evaluated by tests on this design. Many individual properties were also evaluated by tests on other designs of current transformers and on other simpler test samples. For control purposes, samples of asphalt-impregnated paper insulation of the type presently used on dry-type transformers were also included in the tests.

Physical Properties. The physical properties of both the special transformer butyl compound and the present asphalt-paper insulation are shown in Table I. The tensile strength of both materials varies with temperature. As indicated in Figure 5, the direction of lamination affects the strength of asphalt paper, while butyl has the same strength in all directions. At the normal top operating temperature of 85 to 95 degrees centigrade, butyl is stronger than the older insulation, although both are adequate.

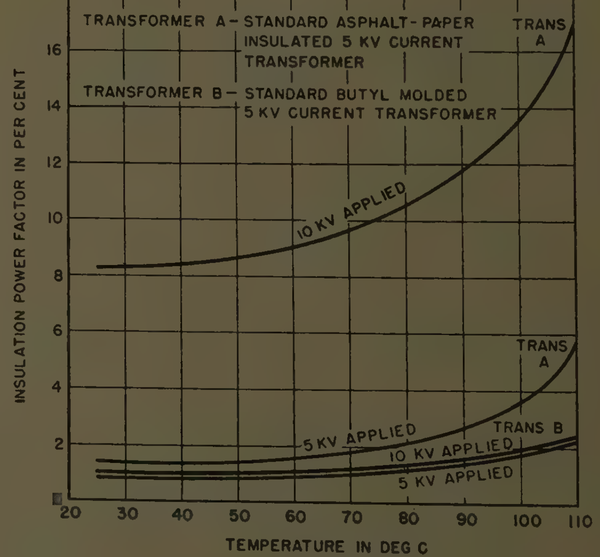

Figure 8. Power factor versus temperature in transformer butyl and asphalt paper

The elongation of butyl is much greater than that for asphalt paper, which is a distinct advantage, since the thermal expansion of parts and severe distortion forces caused by high momentary overloads or accidental rough handling will not crack the butyl. As shown in Figure 6 butyl is much more resistant to mechanical damage than the older style insulation. The depth of penetration listed in this curve is the permanent damage done to the insulation, the depth of the cut in the material after each blow.

Chemical Properties. Comparative chemical properties of transformer butyl and asphalt paper are listed in Table II. Like most organic insulations, butyl compound is attacked by organic solvents, but its resistance to these materials is much greater than that of asphalt paper. Toluene, for example, completely dissolved the asphalt from asphalt-paper insulation in six hours at room temperature. Butyl swelled to a 65 per cent larger volume and its elongation was reduced from 680 per cent to 100 per cent in one day, and very little further change occurred in three weeks. Thus, while butyl is attacked by toluene, the rate of attack and severity of the result are much less than for the older insulation. Carbon tetrachloride and various light oils also gave similar results as indicated in the table.

Acids do not affect butyl appreciably, but do attack asphalt paper. A 30 per cent solution of sulphuric acid left no visible signs of attack on butyl after three weeks at room temperature. Asphalt paper, during the same period, lost most of its tensile strength, probably because the paper was attacked by the acid. Alkalis do not affect butyl but do attack asphalt paper. A ten per cent solution of sodium hydroxide delaminated the asphalt-paper insulation in one day, but showed only a slight surface hardening on the butyl after three weeks.

Butyl is also more flame-resistant than asphalt paper. Both will burn under the right circumstances, but butyl burns much less readily and much slower. A test used by one fire insurance company is to play the hottest part of a bunsen burner flame on the sample for 15 seconds, remove it for an equivalent time, and repeat until the sample continues burning during the entire interval between applications of the flame. Under this test, butyl averaged eight cycles while asphalt paper continues burning after the first application of flame.

Electrical Properties. Comparative electrical properties of transformer butyl and asphalt-paper insulation are shown in Table III. As may be seen, the dielectric strength is much higher for the new material. However, such factors as the

Table III. Electrical Properties of Transformer Butyl and Asphalt Paper Room Temperature

Property	Transformer Butyl	Asphalt Paper
Dielectric strength (volts per mil)*	400	250
60-cycle power factor (ASTM D150, per cent)	0.3–0.8	1.0–3.0
Dielectric constant (ASTM D150)	2.5–3.5	3.0–4.0
Arc tracking (seconds, ASTM-D495-42)	130	130
Volume resistivity (ohms per cubic centimeter)	10^{15}	10^{14} to 5×10^{14}

* Dielectric strength tests made on one-eighth-inch thick samples. Voltage applied in 5-kv steps each of 1-minute duration.

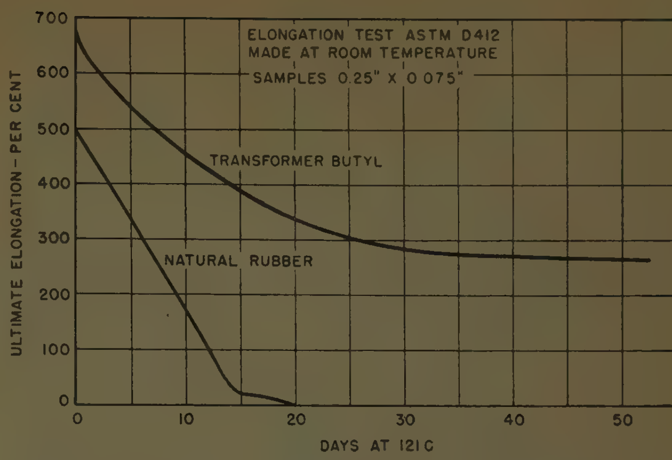

Figure 9. Aging of transformer butyl and long-life natural rubber

Ultimate elongation versus time at 121 degrees centigrade

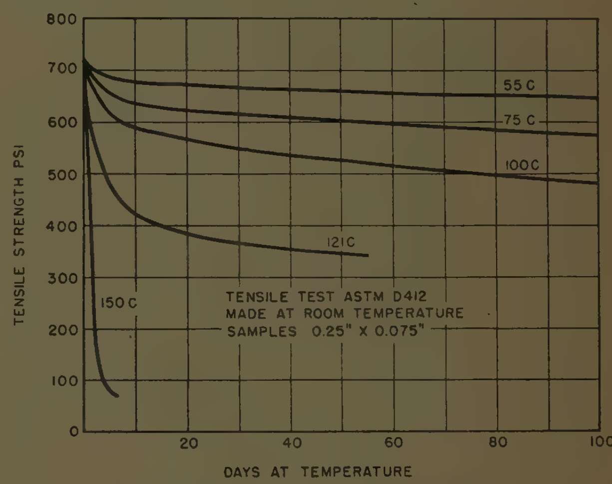

Figure 10. Aging of transformer butyl

Illustrates changes in tensile strength versus time at 55, 75, 100, 121, and 150 degrees centigrade

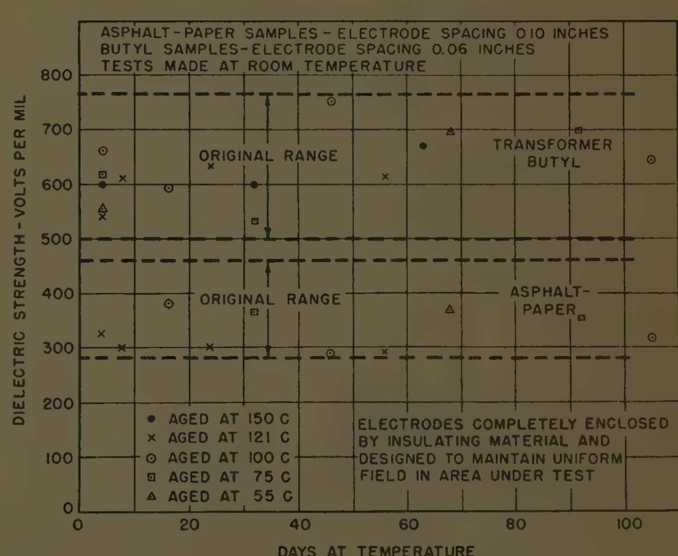

Figure 11. Aging of transformer butyl and asphalt paper

Dielectric strength versus time

thickness of butyl tested, the thickness of the paper, and thus the number of layers, in the asphalt-paper sample, will affect the absolute value of the result. In general the relationship between both types of insulation will be maintained under all ordinary conditions. The effect of temperature on the dielectric strength of both materials is shown in Figure 7.

The insulation power factor is considerably lower for butyl than for asphalt paper. Again, the specific design on which these insulations are used may cause the power factor to vary somewhat from the range indicated which is for the materials alone. The power factor of molded butyl is not appreciably changed by variations in temperature or voltage, which is a distinct advantage. The power factor of asphalt-paper insulation is affected much more as shown on Figure 8.

STABILITY OF PROPERTIES WITH TIME AND OTHER FACTORS

In order to make as complete an evaluation as possible, the ability of butyl to retain its properties under various conditions was investigated.

The effect of time and temperature on the various properties of the special transformer butyl compound is shown in

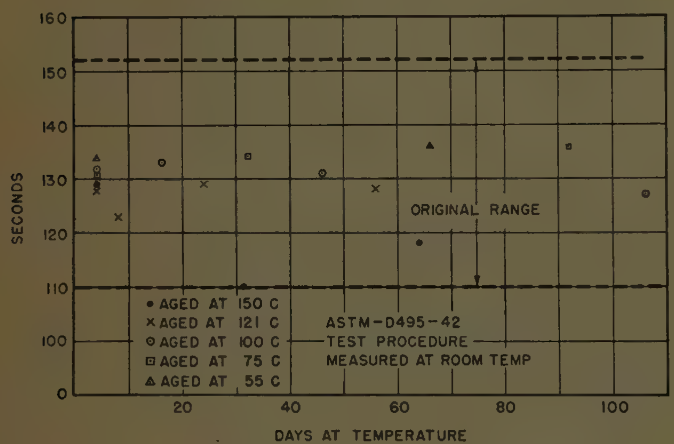

Figure 12. Aging of transformer butyl
Arc tracking versus time

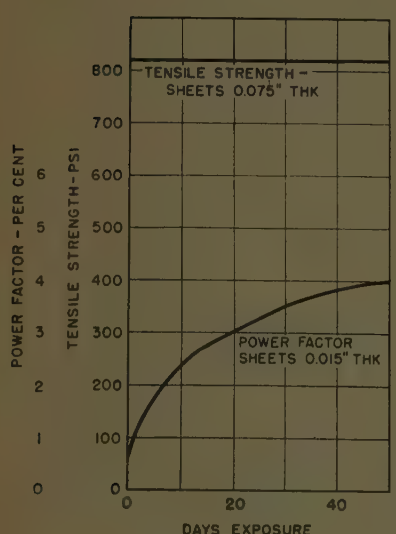

Figure 13. Effect of exposure to 90 per cent relative humidity at 35 degrees centigrade on transformer butyl sheets

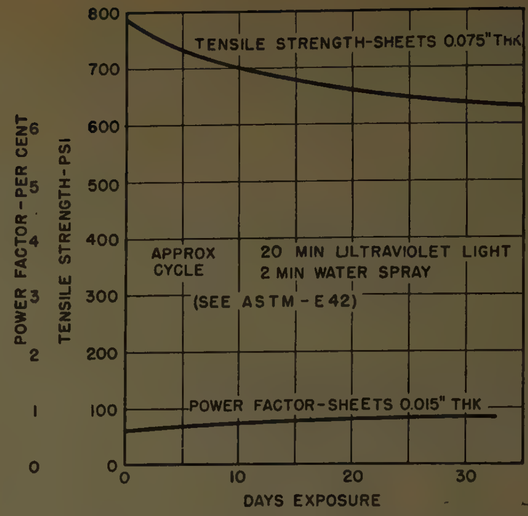

Figure 14. Effect of exposure in weatherometer on transformer butyl sheets

Figures 9 through 12. As shown on Figure 9, butyl at 121 degrees centigrade remains elastic for a much longer period than long-life natural rubber of the type used for cable insulation. Since the normal operating temperature is under 100 degrees centigrade, this test represents an accelerated condition. The change in tensile strength, as shown in Figure 10, is also very small in the operating temperature range. Other physical properties, such as elongation and elasticity, exhibited a similar change with time and temperature.

Because these tests were made on thin sheets of butyl, there appears to be an aging effect. Additional tests have shown that the deterioration of the material is a surface effect, working from the outside in. Complete transformers, for example, exhibited signs of cracking and deterioration on the surface after 1,500 hours at 150 degrees centigrade. However, dissection of the transformers after test showed that good solid butyl existed 1/16 to 1/8 inch beneath the surface, and thin sheets cut from these inner sections showed normal values of hardness and elongation and a 30 per cent to 50 per cent reduction in tensile strength from initial values. Thus, the changes in the sheets which occurred at even 150 degrees centigrade are interesting data, but are not significant from the standpoint of the transformer life. Electrical properties, such as dielectric strength and arc tracking, show no change with time and temperature as indicated on Figures 11 and 12.

Although the new transformer design is for indoor applications only, the effect of humidity and simulated outside weathering conditions on butyl was investigated. Figures 13 and 14 show that continuous exposure to high humidity raises the power factor somewhat, but weatherometer conditions do not change this property significantly. Again these tests were made on thin sheets where the surface effect greatly exaggerates the changes.

Since a small amount (approximately 0.5 per cent) of sulphur is needed to vulcanize the transformer butyl, the possibility of the molded insulation corroding the copper parts of the transformer was investigated. Figure 15 shows typical time-versus-resistance curves for very small wires molded in butyl and exposed to various temperature and humidity con-

ditions. As indicated by the flattening of the curves, the corrosive effect becomes negligible after a short period of time, probably because all the sulphur compounds in the butyl adjacent to the copper are used up, and the rate of additional sulphur penetration to this area is extremely slow.

Corrosion data for various sizes of wire, temperatures, and amounts of sulphur in the butyl are shown in the Graeco-Latin squares of Figure 16 for tests in air and water vapor. The figure, *100% S*, indicates the amount of sulphur (approximately 0.5 per cent) used in transformer butyl. Other amounts, varying as shown from this normal value, were milled into the butyl for the other samples. The percentage figure in the center of each square (*1%*, *4%*, *12%*, and so forth) indicates the ultimate increase in resistance which will occur with the given conditions. Under the worst condition with the normal amount of sulphur (*100% S*), a three per cent increase in resistance was noted. Since a ten per cent increase represents only a 0.00025-inch penetration in 0.010-inch-diameter wire, the corrosive effect of butyl on copper is negligible. The fact that wire sizes normally used in instrument transformers are considerably larger than those used in this test further reduces the significance of corrosion as a factor in transformer life.

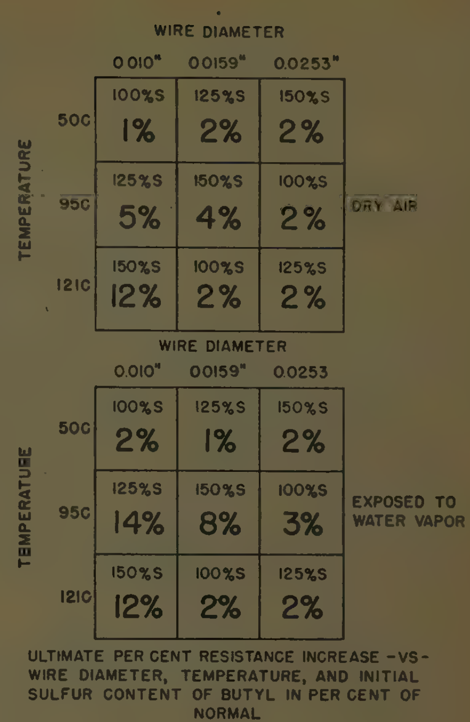

Figure 16. Corrosion and ultimate resistance increase of bare copper wire molded in transformer butyl

Data are given for various sizes of wire, temperature, and amounts of sulphur in the butyl

IONIZATION CHARACTERISTICS OF BUTYL

THE foregoing data indicate that butyl has very excellent properties as a transformer insulation, and that these properties may reasonably be expected to remain constant for long periods of time under the many conditions of use to which transformers might be exposed. However, any insulation material will fail in a relatively short time if it is operated continuously at too high a voltage stress, even though this stress is considerably below the short-time dielectric breakdown value. The importance of this phenomenon has warranted the investigation of many types of material by various methods. In general, the most widely accepted method is that of determining the amount of ionization present at the operating voltage.

As applied to electric insulation materials, ionization is commonly thought of as a phenomenon resulting from the bombardment of molecules by particles of atomic or even smaller dimensions. When the voltage stress is high enough these particles are accelerated to a point where they can free electrons from the molecules of the insulation material and cause ionization.

If no ionization is present at the operating voltage, almost infinite life can be expected. Test samples with round electrodes have operated at 125 volts per mil continuously for 120 days with no deterioration indicated. This life, at a stress in excess of five times that used in transformers, is possible with this type of sample because there is no ionization below approximately 175 volts per mil.

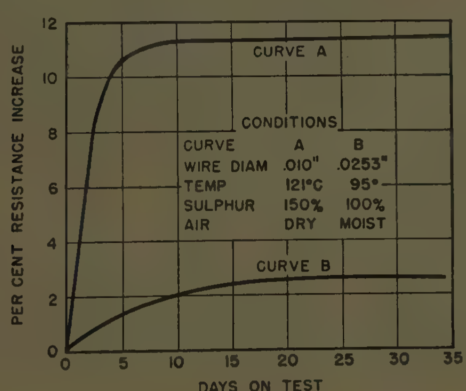

Figure 15. Corrosion of bare copper wire molded in transformer butyl

Typical time-versus-resistance curves

Tests on several hundred transformers of the 5,000-volt design illustrated in Figure 1 have shown that ionization does not start until a voltage well above 5,000 volts is reached, and stops above this value when the test voltage is reduced. Without ionization at the operating voltage, there is no cause for electrical deterioration. This fact plus the excellent chemical and physical stability of transformer butyl makes it an ideal dry-type insulation.

CONCLUSIONS

A NEW solid insulation useful for voltages presently handled by instrument transformers made with dry-type insulation has been described. This insulation, molded butyl, has been applied to instrument transformers and represents a significant advance in the design and manufacture of these devices.

The properties of molded butyl compound are significantly better than those of older insulation, both in initial characteristics, and long time stability under adverse operating conditions.

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Selection, Design, and Operation of Power Transformers

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As power transformers are second in importance only to generators in an electric system, much attention must be paid to the design and operation of them. This article tells of the practices used on the American Gas and Electric Company system in selecting and servicing many types of power transformers.

THE American Gas and Electric Company system is an outgrowth of many originally isolated systems of diverse origin and characteristics. It serves 1,100,000 customers in more than 2,000 communities. Well integrated and thoroughly interconnected with 16 neighboring systems at 36 different points, its transmission extends over an area with a population of approximately 4,000,000 people in seven states. Power is served to some of the most highly industrialized portions of the nation, albeit about one-third of its customers live in rural areas.

System-generating capacity of over 2,200,000 kw is available through transmission and subtransmission networks of various voltages, essentially all operated with solidly grounded neutrals. These diverse voltages (154, 132, 110, 88, 66, 44, 33, 27, 22 kv, as well as numerous lower voltages for distribution use) make the power transformer problem a complicated one, although some of the voltages are restricted to small areas.

While all transformers, regardless of specific use, present many similar basic problems, different factors are stressed depending on the specific application.

Generator Transformers. Transformers used to step up generator output to transmission voltages will be fully loaded when initially placed in service and are unlikely to be required, during their existence, to handle more load. Such transformers are selected with sufficient capacity for any load of which the combined boiler plant and turbogenerator unit is capable without penalizing transformer life. The practice is to specify generator transformers larger than the generator to provide for the inherent plant capabilities above nameplate rating.

Generator step-up transformers will often have more than two transmission voltages, and sometimes a winding will be included for station auxiliary supply, if the economics of transformer design do not bar it. Such a transformer is shown in Figure 1.

Step-Down Transformers. The usual step-down station serves a growing load. Initially a transformer is installed of such size that it will not have to be replaced or supplemented before a reasonable economic period has elapsed. This transformer can take the normal increases in loads until it is no longer economical to load it further even with the benefit of auxiliary cooling. Such transformers do not usually have a sustained maximum demand for more than one or two hours a day. The unit is operated over-loaded during such periods.

The transformer banks are never made so large that they will tie up too much capacity in a single unit. In the ultimate setup of the station there will be two or more transformer banks so that the station capacity is not all in one bank.

Barring other necessities, 2-winding units will be used; but often they will be transformers which step down to both a subtransmission and a distribution voltage, or perhaps two subtransmission voltages simultaneously. Considerable economy results by combining these functions in one transformer.

Transformers used in large stations which serve single industrial customers generally will be found to be 2-winding transformers.

The conventional distribution station utilizes 2-winding transformers of standard design. Single-phase units will range from 100 kva up to 5,000 kva, while 3-phase transformers will be rated from 300 kva up to 10,000 kva.

Many transformers rated 1,000 to 10,000 kva are used for stepping down directly from 132 kv to distribution voltages or to subtransmission voltages in small load centers. These are 3-phase units, and the general setup of such a station will not be different from that stepping down from a lower voltage except that 132-kv circuit breakers and fuses are omitted. A typical station of this type is shown in Figure 2.

Station Auxiliary Transformers. Power transformers ranging in size from 5,000 to 10,000 kva are used to supply generating station auxiliaries. With the unit system, the auxiliary load is carried from two 3-phase transformers connected directly to the generator leads. Two units are used because the large generators have two independent windings, and load is best balanced in that way. It reduces risks and furthers economy by the use of lower-rated auxiliary switchgear. To provide an outside source while starting and stopping generating units and to meet emergencies, a 3-phase unit stepping down directly from 132 kv or other transmission voltage to either a single or two auxiliary voltages is provided.

Essentially full text of paper 50-29, "Selection, Design, and Operation of Power Transformers on American Gas and Electric Company Systems," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12-16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Transformers for Synchronous Condensers. While synchro-
ous condensers are sometimes provided with transformers hat have no other function, they are most often connected o a tertiary winding on a main station transformer bank. Compensators are eliminated and switching simplified by using starting taps in the transformer windings. When t is necessary to have a tertiary winding for other reasons, ufficient capacity is provided in order to allow for the uture installation of a synchronous condenser or static capacitors.

System Grounding. In stepping down from a higher to a ower voltage a Y-connected low-tension winding is preferred to establish a system ground so the best lightning protection and relay operation is obtained. Sometimes, however, this is not possible inasmuch as a Y connection s needed on the high side and the phasing of the system requires a delta connection on the low side. A grounding transformer on the low side is then used. Offsetting this, however, there is often a reduction in the cost of the main transformer by reason of the Y connection on the high side. Generally speaking, where the higher voltages are concerned, the Y-connected high-tension winding is used for economy. If the Y connection is not provided on the high voltage, expensive potential transformers have to be used for relaying.

Inasmuch as the system neutrals are, for the most part, grounded, it is customary, wherever possible, to use high-voltage transformers with graded insulation, and thereby take advantage of economies in design, economics of lightning protection, and the best relaying practices.

SELECTING TRANSFORMERS

Formerly, generator transformer banks and large transformer banks stepping down from the transmission voltage to subtransmission voltages were nearly always three single-phase units with a spare, because the physical size of a 3-phase transformer at that time made such a unit extremely difficult to handle. With increased reliability and decrease in physical size of modern transformers, the 3-phase transformer offers a number of valuable advantages. A single 3-phase transformer without a spare involves a lower first cost but poses a problem when failure occurs. One effective answer is to utilize two 3-phase transformers, either one of which alone is capable of taking care of 60 to 70 per cent of the total requirements. When there are several generator units of similar characteristics and size, 3-phase transformers are used in each case with a single spare unit which is available for use with a number of generators even if they are located at different plants.

A 3-phase unit is not only most economical in first cost but also in its leads, structures, and other associated appurtenances. The banking of single-phase transformers requires complicated connections, whereas a 3-phase transformer can be connected by simple direct leads. Where generating units have multiwindings or multigenerators, a 3-phase unit for each winding or generator is simplest and most economical. An illustration of this is shown in Figure 3.

The use of 3-phase transformers in distribution stations decreases the cost of the station and transformer so con-

Figure 1 (above). Single-phase 4-winding generator transformer, 132Y/27/11/2.3-kv delta 40,000-kva type FOA. Three comprise a 120,000-kva bank; each is shipped completely assembled. The interior assembly has essentially been placed on its side, and the bushings depressed and tilted to limit over-all height. There are two sets of radiators with cooling fans

Figure 2 (below). Transformer rated 1,500-kva 3-phase 132Y/4Y-kv stepping down to a distribution system. This transformer is tapped directly to the 132-kv line through motor-operated airbreak switches, without an intervening circuit breaker or high-voltage fuses. Note the close-coupled 109-kv lightning arrester mounted on the transformer bank

siderably that, except in cases of isolated stations, their use is definitely indicated.

To provide spare requirements and meet emergencies, mobile transformers are available on the American Gas and Electric Company system. Five 3-phase transformers, complete with lightning arresters, are permanently mounted on drop-center railroad cars. Three of these units with a capacity of 15,000 kva each have a high-voltage winding of 132 kv Y and step-down to 110, 88, and 66 kv Y; 44, 33, 27, and 22 kv Y or delta; and 13.2 and 11.5 kv delta. The other two units of 17,000 kva capacity each have high voltages of 88 kv, 66 kv, 44 kv, and 33 kv stepping down to low voltages of 44 kv, 33 kv, 27 kv, 22 kv, 13.2 kv, and 11 kv. Although these mobile transformers were initially planned for emergencies, they proved extremely useful in supplying sizeable war plant loads during the war and in partially alleviating power transformer shortages after the war. One of these mobile car-mounted units is shown in Figure 4.

The possibilities of units of about 50,000 kva similarly mounted are now being studied.

In order to provide quickly available capacity for distribution stations, 11 portable stations are available. Each consists of a 3-phase transformer with high-voltage airbreak switches, fuses, low-voltage oil circuit breaker, and control and protective equipment all mounted on a pneumatic-tired trailer. Each of these stations is capable of supplying power at 2.4/4 kv Y, or 7.2/12 kv Y. These have one of the following high-voltage ratings: 33/66 kv, 44 kv, 33 kv, 27/33 kv, or 22 kv. All of these are 3,000 kva except the 33/66 kv unit, which is 2,500 kva. Forced-oil and forced-air (FOA) cooling is used in all of these cases to obtain light weight and compact transformers.

These portable stations, in addition to furnishing quickly available spare capacity, also are invaluable for by-passing stations during maintenance or station changes and for feeding unexpected load demands while permanent facilities are being constructed.

Figure 3. Three 3-phase 132Y/13.2-kv delta generator transformers at the new Philip Sporn Plant supplying power from a 152,500-kw generator to the 132-kv system. Two units are rated 62,500 kva and one unit 52,500 kva. Two larger transformers connect to the double-winding low-pressure generator and the smaller transformer connects to the single-winding high-pressure generator

Autotransformers are used wherever the ratio of transformation is between 1 and 2 and the systems to be interconnected are in phase. Autotransformers are much cheaper, smaller in size, and have lower impedance and losses than corresponding 2-winding transformers. All autotransformer banks in the system are Y connected with a delta tertiary. This tertiary winding has been used for synchronous or static condensers, subtransmission voltage supply, and generator input. The major autotransformations are from: 154 to 132 kv, 132 to 110 kv, 132 to 88 kv, 132 to 66 kv, and 66 to 33 kv.

Each combination of high- and low-voltage rating, together with the method of cooling, has a corresponding band of impedance within which the most economical transformer can be designed. For transformers stepping down to distribution voltages, an impedance at the lower limit of the economical band is selected. This facilitates the paralleling of transformer banks, when necessary, without loss of capacity. For transformers stepping down to subtransmission voltage where more than one station feeds an interconnected subtransmission system, impedances have to be selected so that the stations will divide the load in proper proportion. The transfer of large blocks of power on the transmission system complicates this problem, and a thorough calculating board study of the system in these cases is made to determine the optimum impedances for the transformers. When selecting impedances for 3-winding units transforming to a subtransmission system with the tertiary winding used for a static or synchronous condenser, the impedances are selected so that the condenser will be electrically close to the system to be regulated. When the subtransmission voltage is the one to be regulated, this impedance relationship falls within the natural economic design of the transformer, but when the transmission system is to be regulated, it entails special arrangement of windings with consequent higher cost, weights, and losses.

Self-cooled transformers with provision for the future addition of fans are used up to 10,000-kva bank capacity, while larger units have forced-air cooling. Subsequent to 1930, with one exception, no water-cooled transformers were purchased, but by 1941 developments in forced-oil forced-air cooling made possible the acquisition of a 120,000-kva generator transformer bank, the single-phase units of which were shipped completely assembled with all bushings in place. It is believed this unit was the first of its kind in the large power class. To obtain maximum reliability, the power supply for the fans and pumps is contained within the main power transformer and is provided in duplicate so that either supply can operate all fans and pumps. The fans and pumps are also divided into two similar groups so that in case of trouble with either group the transformer will still carry 70 per cent load. Figure 5 shows such a unit.

While no specific requirements have been made as to the ability of transformers to carry overloads, this thought is always in the picture. Any transformer that reaches an overload condition which cannot be relieved immediately

Figure 4. Railway portable transformer rated 15,000 kva temporarily installed to supply a customer from 132-kv lines while permanent facilities are being constructed (Carswell, W. Va.)

is subjected to detailed study to determine the possibilities. Usually some expedient can be found to carry the load required. In the case of multiwinding transformers, light loading on one of the windings enables the others to carry substantial overloads.

In designing larger distribution stations where bus regulation is required, it is found most economical to include low-voltage tap changing under load in 3-phase transformers where the capacity is 5,000 kva or more. In smaller stations, it is often more economical to use a separate step-voltage regulator for bus regulation.

Special fire protection for transformers has been used only in a relatively few cases. Generally speaking, these involve generator step-up transformers. In a few instances automatic sprinkler systems, using spray nozzles to extinquish the fire, have been installed.

A larger number of protective schemes on generator transformers using carbon-dioxide as the extinquishing agent have been installed. In many cases fire barriers have been built between adjacent transformers when they were located in important installations. Such an installation is shown in Figure 5.

For the most part, however, special fire-protective barriers and extinguishing systems have not been applied to power transformers. The fire-protective and extinguishing equipment supplied for a station as a whole has been selected to be adequate for transformer fire protection.

TRANSFORMER DESIGN

The modern transformer is lighter and has smaller dimensions than formerly. This is directly reflected both in the initial cost of the transformer and in the lower costs of installation. Less costly foundations are required; less expensive structures will suffice.

It has often been found economical to utilize transformers having three or four windings, and consideration has been given to units having five windings.

As the number of windings increases, design problems become more difficult. Only in the larger size transformers is it feasible to have these extra windings because of the lack of space on the outside of the smaller transformers to locate the various bushings and other accessories. There is a distinct saving in first cost when transformer capacity is attained by including additional windings, and there is an equally attractive saving in foundations, structures, and simplified switching.

In the higher voltage transformers it is customary to place a sufficient number of taps in the high-voltage winding to cover the range of voltages which is likely to be encountered. Except in rare cases, this range will not exceed ten per cent of the rated voltage, nor will more than five taps be required. In the lower voltage and the smaller transformers it has been necessary to consider past practice in arriving at taps and tap ranges. Consequently, through the year specifications have been changed so that the new transformers would parallel at least partially with the old ones, but at the same time attempts were made to keep the tap range and the number of taps within standards which would not make first cost extremely high.

In a 2-winding transformer the tap situation is relatively simple. One winding needs no taps at all, and the other can be designed to cover the voltage range which the transformer must serve. In 3- or 4-winding transformers taps are needed in all but one of the windings to provide the same flexibility attained in 2-winding transformers.

LIGHTNING ARRESTER APPLICATION

As field research determined the characteristics of natural lightning, and laboratory work disclosed the effects of lightning on transformer insulation, and as the protective characteristics of lightning arresters were better understood, it was possible to co-ordinate all factors on an engineering basis.

As the result of a careful study it was decided to reduce

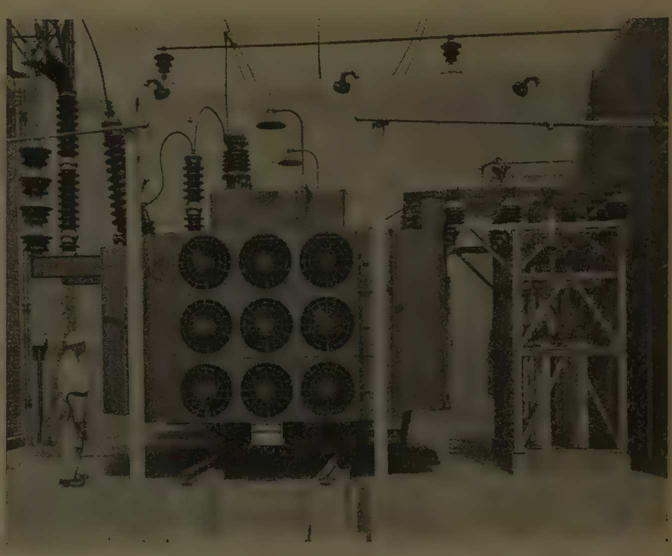

Figure 5. A modern single-phase 42,500-kva FOA-type transformer. This unit is one of a bank connecting the 13.8-kv number 2 double-winding generator at The Ohio Power Company's Tidd Plant to the 132-kv transmission system. On this unit, note close-coupled lightning arresters, the compactness of the unit, and the installation of CO_2 piping for fire protection

lightning-arrester ratings over the entire high-voltage system, and this resulted in marked improvement in transformer performance against lightning surges.

The success of this forward step was followed by further study of the possibility of reducing transformer insulation below the then accepted industry standards of impulse values of full rated insulation, and co-ordinating the transformer strength with lightning-arrester protective levels was undertaken. This resulted, in 1934, in adopting the so-called reduced insulation on a 30,000-kva 132-kv transformer bank where a lightning arrester of reduced rating was mounted directly on the transformer bank. In this way, it was possible to use 115-kv-class insulation for the transformers on the 132-kv grounded-neutral system with an overall saving in the order of 15 to 20 per cent. This practice has been continued up to the present time with complete transformer protection and service that has been entirely satisfactory.

During the last 16 years, there have been installed on the American Gas and Electric Company system nearly 3,750,000 kva of transformer capacity in the range of 88, 132, and 154 kv, all having reduced insulation—that is, one level below the standard basic insulation level values. Practically all of this kilovolt-amperage capacity has been impulse-tested at the factory. In almost all cases where reduced insulation is used in the transformer windings, bushings likewise have a reduced insulation rating. The saving in first cost of the transformers alone has been estimated at 1.5 million dollars. Some 500,000 kva (13 per cent) of transformer capacity tested, has, as far as is known, failed during factory impulse test.

Commercial factory impulse tests have been a valuable and indispensable means of proving that the transformer strength specified actually is obtained. In 12 cases of transformer failures that occurred on factory tests, defects in the design or faulty workmanship or material were found in every case.

Reduced insulation practice has not been carried into or below the 66-kv class of transformers, as no transformer cost reduction has been indicated by the manufacturers of these transformers.

In all cases where reduced transformer insulation has been applied, 30 per cent margin or more between the lighting-arrester protective level and the transformer full-wave tested strength has been obtained.

TRANSFORMER OPERATION

About 1932, in connection with the power-factor field testing of bushings, insulation testing of the larger power transformers was started. This test work has expanded steadily, and numerous conditions hazardous to safety and continuous operation of transformers have been found in this way and corrected before costly failures occurred. Field power-factor testing of large power-transformer insulation is now done on a routine basis. Tests are being made periodically at approximately 3-year intervals. These tests include not only transformer windings, but transformer bushings and oil as well. A special field-test set is also used to determine oil neutralization number and color where the oil is questionable. In addition, dielectric tests of the oil are made at much more frequent intervals. In cases where field tests have shown the oil questionable, a detailed oil analysis is made in the laboratory and, based on laboratory recommendations, the oil is reconditioned or reserviced as required.

While formerly very elaborate fixed pumping systems, with large amounts of pipe laid in the ground, were used, much of this has been eliminated. General practice now is to utilize portable pumping and filtering equipment which can be moved directly to the apparatus being treated and use flexible tubing or other portable piping. This transition from the elaborate oil-handling and purifying schemes of the past has resulted in a tremendous saving not only in equipment, but in building space.

Reclamation of oil is carried out by filtering through Fullers earth when necessary.

All of the larger transformers have differential-relay protection. Generator transformers do not have overload protection; but, generally speaking, the transformers in step-down stations do. Frequently, generator transformers will have not only a separate differential-relay system but also differential-relay protection to include both the generator and the transformers.

Transformers in the large sizes, and especially those with forced-oil forced-air cooling, have been provided with thermal relays which function if operating temperatures are exceeded (which may result from loss of air or oil pressure). While some advocate tripping the transformer off the line when these relays operate, in this system the alarm gives a warning signal only.

Although it was general practice in past years to move spare transformers to replace a damaged unit, the time and effort required resulted in serious delays in restoring service Now the spare transformer is arranged so that it can be cut in and out of service to replace any regular transformer without physically moving it.

In a few isolated cases, substitution of the spare transformer for one of the others has been carried out without de-energizing the transformer bank by using hot-line tools to do the work.

Minor repairs are carried out at the site. For major repairs, the transformer is usually moved to a location where there are adequate shop facilities. Such facilities are available on the American Gas and Electric Company system at a few of the older major stations. Experience has shown, however, that these were seldom used; hence, in later stations they have not been furnished. Major transformer rebuilding or repair is best handled by transporting the transformer to the factory or manufacturer's service shop.

Most field overhauling of large transformers has been carried out by the use of *A* frames and temporary shelters. At a number of points on the system it was customary in years gone by to install permanent *A* frames usually at large transformer stations. Now it is more economical to set up temporary wood-pole *A* frames with canvas shelters for carrying on this work.

Smaller-size transformers are best moved to a point where hoisting and other facilities are available. This point may very well be the manufacturer's service shop or a company service shop.

A New High-Accuracy Counter-Type Tachometer

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C. L. BEATTIE

THE EFFICIENCY of some present-day power equipment such as steam turbines, gas turbines, electric motors, and others has reached the point where further efficiency increases may be of the order of one per cent or less due to a particular design change. Since the output of a prime mover is obtained from torque and speed, these two quantities must be measured with high accuracy for accurate efficiency results. Present standard tachometers are simple in principle but reach a maximum useful accuracy of about one per cent. Often, however, the over-all probable inaccuracy is greater than the small change in efficiency expected due to a design change.

To get dependable accuracies better than one per cent, high-precision methods must be employed. This precision tachometer is accurate to better than 0.03 per cent of the reading for all speeds from 400 to 15,000 rpm. Its accuracy results from counting pulses electronically from a permanent magnet generator for a precise length of time. The indicator, as shown in Figure 1, presents the speed in number form, so no interpolation by the operator is necessary. The time standard is a temperature-stable tuning fork accurate to within 0.002 per cent. No calibration adjustments are required.

The operation of the system may be explained with the aid of Figure 2. An a-c signal is generated in the pickup due to magnetic poles on the periphery of the rotating drum. The number of cycles generated per revolution is fixed so that the total number of cycles counted during the counting period of 0.8 second is equal to the actual speed. The range from 4,000 to 15,000 rpm requires a 75-cycle-per-revolution track on the drum. For speeds between 400 and 4,000 rpm, a 750-cycle-per-revolution track is used so that the first digit of the total cycles counted will indicate tenths of revolutions per minute. The switchover from the low-range track to the high-range

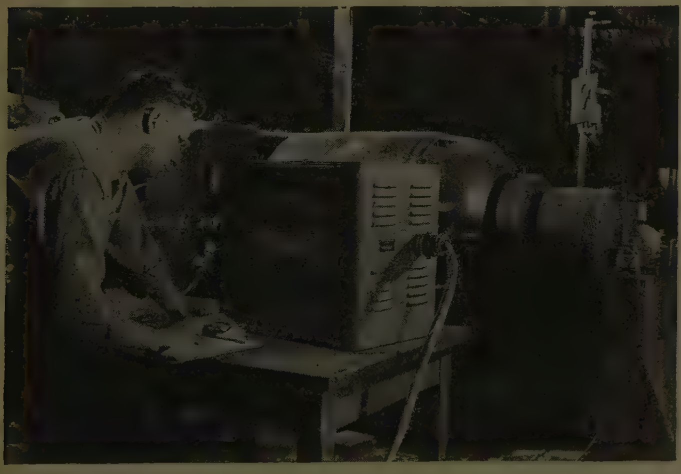

Figure 1. Tachometer in use showing indicator and generator; electronic cabinet is not shown

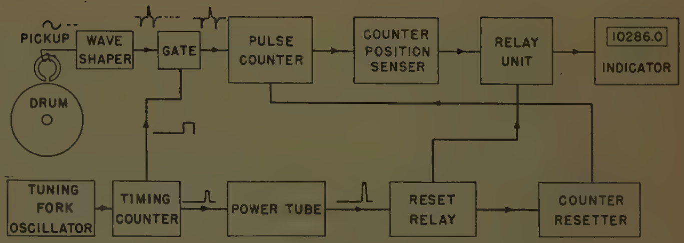

Figure 2. Block diagram of system

An a-c signal is generated in the pickup due to magnetic poles on the circumference of the rotating drum

track is automatic, and there is no change in method of reading the indicator because the first or tenths decade is by-passed by the signal on the high range.

The generator signal passes through a wave shaper and an electronic gate controlled by a timing counter. The basic element of the time unit is a 1,000-cycle-per-second tuning fork. The fork controls an oscillator whose output drives three electronic binary decade counters in series. Each decade counter divides the frequency by 10 which provides an output of one cycle per second with other voltages which occur at 0.8 second and 0.9 second of each one-second cycle. With those voltages, the gate is open for 0.8 second and closed for 0.2 second of each one-second cycle. The pulse counter consists of six binary decade counters in series. At the end of each counting period of 0.8 second, the counters have accumulated the total number of pulses developed by the generator. Each decade represents a digit of the total number.

The counter position senser controls a set of four relays per decade in the relay unit which are so connected to the indicator that the binary count on each decade is transformed to a single digit number in its proper position on a screen. The relays connect power to lamps which illuminate number stencils whose image is focused on the screen. All ten numbers of each digit are focused on a single spot.

The reset relay is energized between the times 0.8 and 0.9 second of each cycle. During this time the counter position senser is allowed to change the relay unit, if necessary, to make it conform to the new count on the pulse counter. This new count is then locked in at the 0.9-second point, and the counter resetter sets all the six decade counter units to zero which completes one cycle of operation. The indicator presentation is continuous except for the digits which change instantaneously when necessary at the end of each cycle.

Digest of paper 50-109, "A New High-Accuracy Counter-Type Tachometer," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R. I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Mathematics in Engineering—A New Policy

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ENGINEERING, and particularly electrical engineering, has become a science whose future progress depends largely on the extensive use of mathematics and physics. In the writer's early experience it was not unusual to hear prominent engineers state that the place for an integral sign is the violin. The use of complex numbers in circuit analysis, the introduction of operational and transform methods, and the application of tensor analysis in electrical engineering have brought to our profession the realization that not only the integral sign, but also other mathematical hieroglyphics, are indeed just as essential to the engineer as they are to the mathematician.

The AIEE Committee on Basic Sciences, recognizing the implications of this extensive use of mathematics, has created a Subcommittee on Applied Mathematics. The purpose of this subcommittee is to establish a closer relationship between engineers and mathematicians. As a means of fulfilling its task, the subcommittee has held five conferences on applied mathematics at annual or winter meetings which have attracted large audiences.

To enhance the value of their services to the AIEE membership, the Committee on Basic Sciences and the Subcommittee on Applied Mathematics have decided to embark on a new policy of inviting the members to submit engineering problems for possible solution by the subcommittee. This policy may be put into effect in this way:

1. The Subcommittee on Mathematics will be enlarged to include prominent mathematicians.
2. The Institute membership will be invited, and is hereby invited, to send problems requiring the use of mathematics to the chairman of the subcommittee who, in turn, will have these problems translated into mathematical language and submitted to the mathematicians.
3. After each problem has been solved, the solution will be retranslated into engineering language and given to the person originally submitting the problem.
4. The solutions will be made the subjects of discussions at future conferences on applied mathematics and will occasionally be recommended for publication either in *Electrical Engineering* or in the *Transactions*.

It must be emphasized that this plan is on a trial basis. We would like to find out from the members whether it is practical and of sufficient value to warrant permanent adoption. To this end, the subcommittee extends an invitation to members of the Institute to submit their problems for possible solution. Naturally, the committee cannot guarantee to solve every problem which it receives. Some of the problems might prove too difficult; others might involve lengthy computations; still others might be too specialized to be of general interest to Institute members.

The subcommittee considers that a problem has been solved when the answer is reduced to a form which lends itself to numerical computations. No numerical work will be done by the subcommittee, although possible methods, utilizing computing machines, may be suggested.

It is obvious that the success of this project depends on two factors: the co-operation of the mathematicians; the co-operation of the membership of the AIEE.

After the decision was made to proceed with this plan, several top-flight mathematicians from the best universities in the United States were contacted. In a letter to these mathematicians the plan was outlined and a reply was requested, indicating whether they cared to serve. It is a pleasure to record here that acceptances amounted to more than 70 per cent. Indeed, in several instances those who accepted expressed enthusiasm for the project and were of the opinion that such a plan should prove mutually beneficial to both mathematicians and engineers. Here are the names of some of the mathematicians who have kindly agreed to co-operate: Professors Garrett Birkhoff and D. V. Widder of Harvard University; Norbert Wiener of Massachusetts Institute of Technology; John Von Neumann and Max Woodbury of the Institute for Advanced Study; John W. Tukey of Princeton University; Mark Kac and Harry Pollard of Cornell University; J. J. Stoker of New York University; A. E. Heins and R. J. Duffin of Carnegie Institute of Technology; and D. G. Bourgin, University of Illinois.

It is the purpose of this article to outline the project and secure the co-operation of the membership in making it a success. The Subcommittee on Applied Mathematics believes that there are many problems in electrical engineering which can and should be solved. Obviously, the various technical committees are more familiar with the problems in their respective fields than is the individual engineer. It is therefore requested that the various technical committees examine their fields and call the attention of the Subcommittee on Applied Mathematics to problems which require the use of mathematics. This, in our opinion, represents the richest source of problems. This does not imply, however, that the subcommittee will not consider problems coming from individual members.

This activity is a service rendered by the Institute to the sciences of engineering and mathematics. Its object is to encourage engineers to use mathematics more freely and to enlist the interest of mathematicians in the application of their science to technology.

The subcommittee would appreciate the reader's opinion of the project as a whole, of its practicability and of its value to the membership. Please convey to the author your reaction to this plan and send him your problems.

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Four Electromagnetic Propositions, With Fluid Mapper Verification

A. D. MOORE
FELLOW AIEE

The fluid mapper is used to answer questions concerning the fields surrounding current-carrying conductors. It is shown that any array of iron of infinite permeability arranged in an array of parallel currents may be replaced by enclosing current sheets which are parallel to the main current. It is also shown that current may be distributed symmetrically in any manner about the axis of a round conductor without affecting the field outside the conductor.

A METHOD has been devised to give a visible representation of a magnetic or electrical field. Since reference can be made to another paper[1] in which fluid mappers have been described, a very brief description must suffice here. In Figure 1*A*, a thin and uniform flow space would be provided between the flat face of a slab and the lower surface of a piece of plate glass. A hole or well in the slab, where the conductor is simulated, provides fluid entry; thus it is a source. The iron is represented by a barrier. If the slab and plate were of infinite extent, and if the flow is kept to within the stream-line range, fluid-flow lines would simulate magnetic equipotentials, and isopressure lines would simulate flux lines. If a finite slab is made large in all directions as compared with the distance from the source to the singular point *S*, a close agreement with the idealized case could be secured.

The flow pattern can be mapped and the map analyzed for relative pressures. Along the barrier *LSR*, the highest relative pressure is at *S*, with pressures decreasing to right and left.

Four propositions concerning 2-dimensional fields will be discussed here. By the first proposition, there may be any array of parallel currents, along with any array of iron rods or other iron shapes, the iron having infinite permeability; then, all of the iron can be replaced by enclosing current sheets, the elements of which are parallel to the main currents.

By the second proposition, in any array of currents and iron as above, any current symmetrically distributed about the axis of a round conductor, may be centered, or otherwise symmetrically redistributed in the conductor, without affecting the field outside the conductor.

Ample verification of the second proposition is given by two series of cases of three each, set up and operated on fluid mappers.

By the third proposition, the first proposition is extended by permitting an iron shape to have finite and differing permeabilities, such iron being replaceable by an array of parallel current filaments distributed over the iron section area.

By the fourth proposition, the second proposition is extended to permit redistribution of currents in round conductors, even when iron containing finite and differing permeabilities is present.

These propositions are confined to 2-dimensional fields. After originating them, the writer tried them out on a number of very able electrical engineers; and to them, they were unfamiliar. However, they turned out not to be new. The writer is indebted to Dr. W. R. Smythe of Pasadena for showing them to be fairly well known to physicists working in electric and magnetic fields.

PROPOSITION 1

Let there be any array of parallel (nonmagnetic) conductors, in air, carrying any desired currents. Rods or shapes of iron having infinite permeability, from one to any number, placed parallel to the conductors, may be present. One of the iron sections may entirely surround the array, if desired. Then, any or all of the iron shapes may be entirely replaced, each by an appropriate current sheet or sheets, leaving the air part of the field unchanged.

In the first case illustrated, Figure 1*A*, a single current

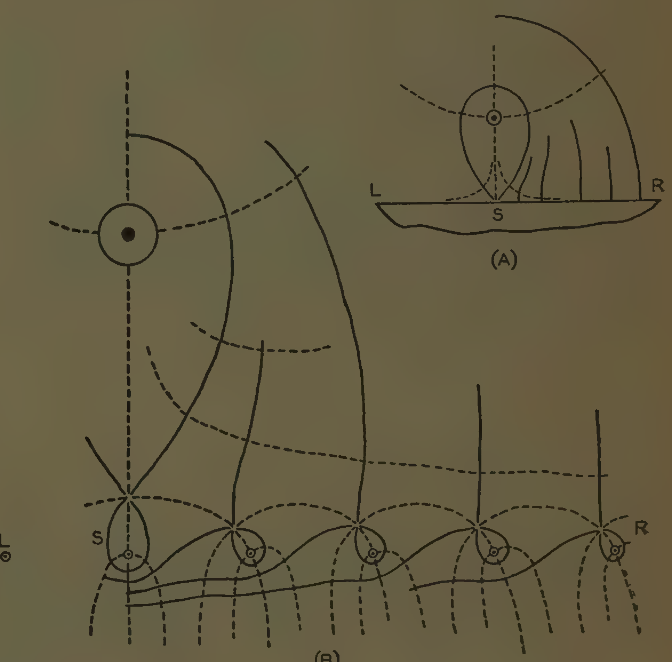

Figure 1. (A) Field of a long conductor, parallel to plane face of iron of infinite permeability. (B) Iron replaced by a surface current sheet; also may be interpreted as fluid flow

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is placed parallel to the plane face *LSR* of an iron mass of infinite permeability and infinite extent. This familiar field has been sketched rather than accurately plotted, in Figure 1*A*. The proposition says that the iron may be removed, and replaced by a certain current sheet *LSR* as in Figure 1*B*, without changing the air part of the field.

The argument is most easily followed if the thinking is done in terms of fluid flow for the similar case, as set up in a fluid mapper.

In Figure 1*B*, the barrier in the fluid mapper has been removed and replaced, along *LSR*, by an infinite number of tiny sources, each theoretically adjustable as to flow strength, or rate of flow. In theory, adjustment could be made until the pressures along *LSR* would duplicate those found from the analysis of Figure 1*A*. Then, all fluid originating in the line of sources would have to flow downward and outward; and the upper flow, originating at the conductor source, would be strictly confined to its own domain. This upper flow could then only duplicate its previous performance.

Electromagnetically, the iron has been replaced by a current sheet whose elements are parallel to the conductor and in the same sense as the conductor current. Now there is nothing but parallel currents setting up a field in air only.

The flux of any tube, which previously returned in a hidden way in the iron, now is given a definite return path in air, below the current sheet.

Note that in Figure 1*B*—which is a sketch—the little sources have been put in at equal intervals. This by no means implies that the sheet's current distribution is uniform. And so far, it has been shown only that there can be an appropriate current sheet for replacing the iron and that, in theory, it could be determined.

The experimental determination of current distribution in the current sheet might most easily be carried out by building a fluid mapper in which the entire flow of Figure 1*B* is made to occur. Both the main source and the distributed line of sources would be operated, but instead of using a great number of small sources along *LSR*, a narrow, compartmented sandbed is used. Only the right half of the case need be built. Each tank, connected to its compartment, is adjustable. Tank levels are adjusted by trial and error until the two areas of flow are each confined within their own domains. Mapping of the lower pattern, and consequent analysis, could be made to yield the facts concerning current distribution in the sheet.

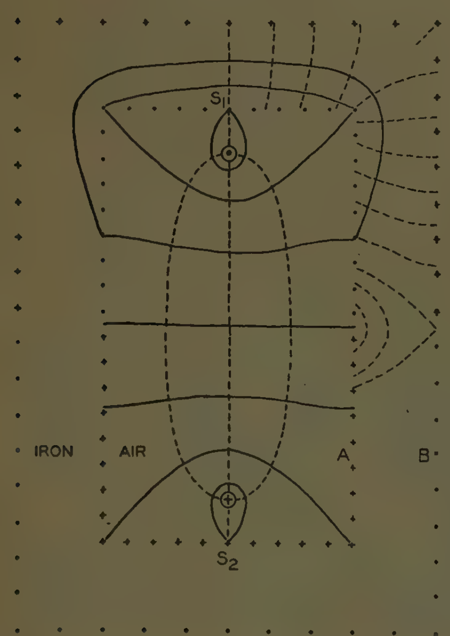

Figure 2. **Equal and opposite currents enclosed at first by iron of infinite permeability; iron then replaced by surface current sheets. Also to be considered in terms of fluid flow in a fluid mapper**

In Figure 2, Proposition 1 is illustrated by a more complicated case. The two conductors, with equal and opposite currents, are completely enclosed in a rectangular tube of iron of infinite permeability. The field is diagrammatic, in that it merely has been sketched. In the fluid mapper, the iron is simulated by a complete surrounding barrier whose inner edge is boundary *A*. The fluid flow is confined to the region inside boundary *A*. The upper conductor becomes a source, and the lower, a sink. Again, with appropriate mapping of the flow pattern and subsequent analysis, relative pressures at the barrier can be found. If zero pressure is assigned to the middle isopressure line, then S_1 has the maximum positive pressure, and S_2 an equal negative pressure.

The iron will now be replaced by two current sheets *A* and *B*, which means in the fluid mapper that when the barrier is removed, a line of appropriate sources and sinks must be provided on line *A*, and also on line *B*. Actually, the installation of the line *B* sources and sinks can be avoided by simply making the slab boundary to conform to line *B* and letting the edge be open. Fluid flow will then be orthogonal to line *B*. All along line *A* a narrow, compartmented sandbed is installed. With the main source and sink in action, tanks connected to sandbed compartments could be adjusted by trial and error until the inner flow is confined precisely to its domain. Due to symmetry, only one-fourth of the case would need to be built.

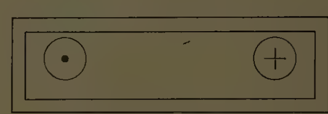

Figure 3. Equal and opposite currents in large, round, solid conductors, enclosed by iron of infinite permeability

When in adjustment, the outer flow will have provided the varying pressures existing in the mapper which previously had been barriered, and the inner flow will have retained its identity. Since line *A* is not an isopressure line, outer flow lines leaving it do not leave orthogonally. The sketch indicates trends. By mapping analysis, current-sheet distributions could be found.

Returning to electromagnetics, fluid sources and sinks are all equivalent to currents, which are all parallel and set up a field in air only. The iron has then been replaced by two current sheets. And note again that inner flux tubes, which previously returned somehow in iron of infinite permeability, now have definite return paths in air, in the region where the iron was.

It is important to note that Proposition 1 is not confined to currents in round conductors. Conductor section and

current distribution in the section can be anything whatever. Neither is it confined to symmetrical cases.

PROPOSITION 2

Within the limits stated for the first proposition, (a) if there is a current uniformly distributed over the section of a round conductor, that current can be centered (axially concentrated) without disturbing the field outside the conductor boundary; or (b) any or all of any number of such currents can be so centered; or (c) more generally, a current symmetrically distributed about an axis can be symmetrically re-distributed in any way whatsoever within the conductor boundary, without disturbing the field outside that boundary.

This is a special outcome of Proposition 1. To prove it, any iron is removed and the appropriate current sheet or sheets is substituted for it. Nothing but parallel currents, in air, is left. It is evident that then, a "round current" can be handled as stated above, without changing the field as delimited.

Verification. In Figure 3, two large, round conductors carry equal and opposite currents uniformly distributed over the sections. They are surrounded by iron of infinite permeability. The two halves are symmetrical, hence only the left half need be simulated. The fluid mapper of Figure 4 has a round sandbed acting as a uniformly distributed sink, to simulate the current. Outside the sandbed, the flow lines correspond to equipotentials. Inside, they correspond to lines of no work.

The next slab, Figure 5 is identical with the previous slab, except that a small sink is provided at the point where the sandbed center would be. We have now "centered" the current. In Figure 6, using the first ring sandbed ever built, we again, in effect, re-distribute the current, this time into a uniform tubular current concentric with the original. When any two of the three photographs are superimposed, virtually exact agreement is found for the fields outside of the sandbed margin. This is really striking, in view of the profound differences between the field within the sandbed (or solid current) and that within the ring sandbed (or tubular current).

Since it might be held that perhaps this series of cases happened to be miraculously specialized and did not furnish sufficient verification, a second series is presented. The complete case is shown in Figure 7. Only the lower left quarter of it was given fluid mapper simulation. The results are shown in Figures 8, 9, and 10; and again, the three fields which are outside the sandbed margin beautifully agree.

Be it noted that this agreement not only verifies the theoretical basis for Proposition 2, but also shows that such fluid mappers can be built—by what are now routine methods—to yield solutions for such difficult problems with high accuracy.

Part of the writer's urge to invent the sandbed feature as a means of simulating distributed-source phenomena, came from his wish to verify Proposition 2 experimentally; and the first sandbed ever built, in October 1943, was generally like that of Figure 5. Although it was not a high-accuracy job, verification was then secured.

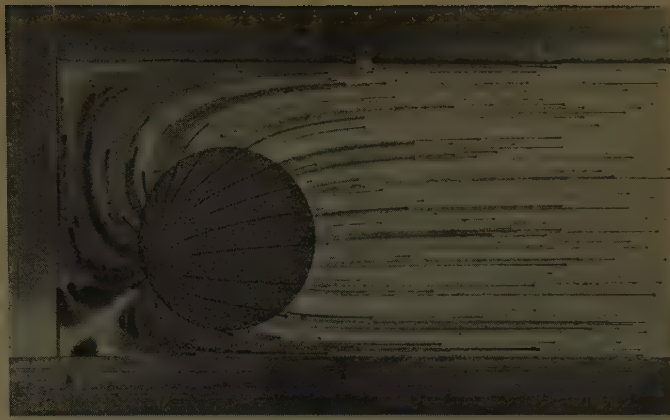

Figure 4. Sandbed fluid mapper simulation of left half of Figure 3. The round sandbed is a uniformly distributed fluid sink

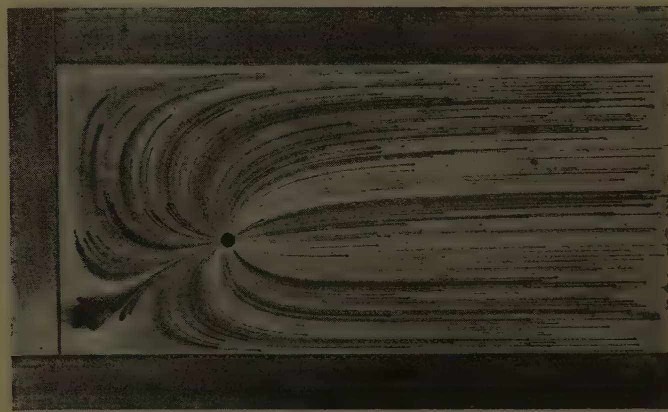

Figure 5. Representing the large, round conductor's current as being centered

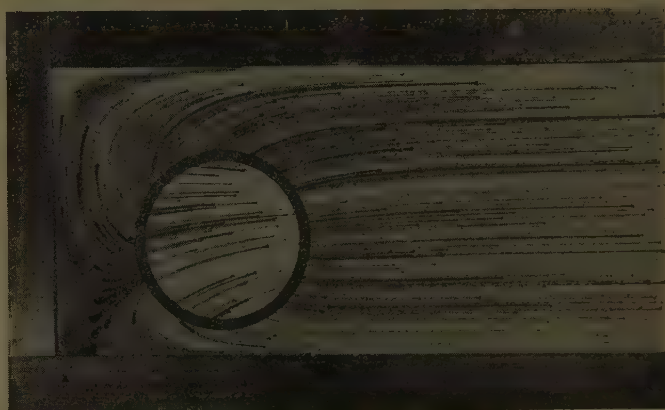

Figure 6. Representing the current as again being distributed to tubular form, concentric with the original

It should be stated that Proposition 2 also is not confined to symmetrical cases, except as to current symmetry in the round conductors.

Application. Consider a case in which only round currents are present (solid or tubular), with iron of high permeability also present. Taking the iron to be of infinite permeability often introduces very little error. All currents can then be centered temporarily. It is often then possible to do graphical field mapping, getting a quite good map within a short time. This map will then be valid

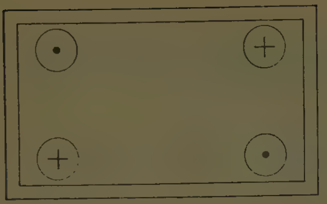

Figure 7. Four equal currents flowing as shown, each in a large, round, solid conductor, and surrounded by iron of infinite permeability

Figure 8. Fluid-flow simulation, by means of a sandbed fluid mapper, of lower left quarter of Figure 7 showing current flowing uniformly in the conductor

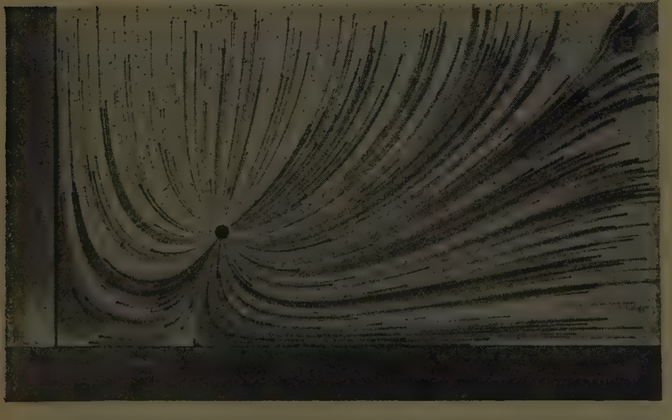

Figure 9. Simulation of Figure 8 when the current is concentrated in the center of the conductor is accomplished by using a small sink instead of a sandbed

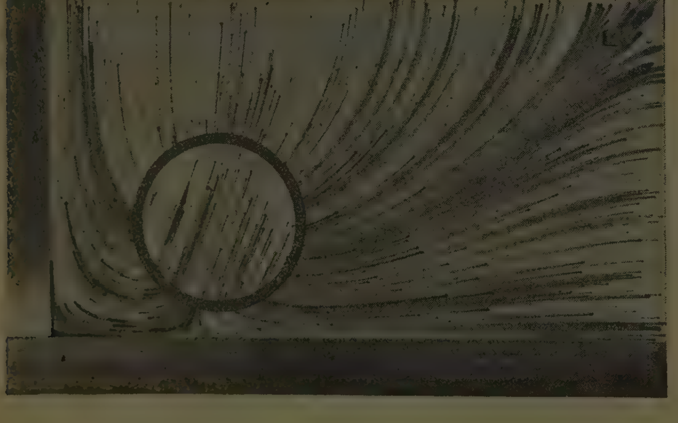

Figure 10. Simulation of Figure 8 with the current redistributed in tubular form, concentric with the original, with a sandbed used to give uniform flow

outside of the real conductor boundaries. Moreover, if kernel locations can be guessed, at least fairly well, equipotential lines coming to the boundary of a solid conductor can be drawn across it as lines of no work, without refraction, and sketched to the kernel, keeping in mind the principles involved in dividing the conductor section into areas appropriately related to potential differences. Remarkably good approximate work can often be done in a short while, leading to an understanding of the phenomena, and even to good values of inductance.

PROPOSITION 3

This is a repetition of Proposition 1, except that instead of having infinite permeability, any iron shape may be of real iron having any permeabilities whatever (but limited to there being a 2-dimensional field). In this case, the iron can be replaced, not by current sheets, but by currents distributed over the area of the iron section.

For illustration, the enclosing iron of Figure 2 now becomes real iron, having finite permeabilities, differing from place to place, as dictated by the type of iron and by the total situation. If the field solution could be foreseen, then a fluid mapper simulation could be carried out, using a large slab extending much beyond B in all directions. The iron section area becomes a flow space also, as does all the region outside of B. Inside of A and outside of B the same uniform flow space is used. But in the iron-section area, the flow space is reduced in differing degrees, using the spacing-cubed[1] law to make all spacings appropriately correspond to their respective permeabilities. Only the source and sink representing the two currents would be used. Then flow lines (corresponding to equipotentials) would in some degree and in some manner cross the iron-section flow space, and a pattern would appear outside of B, corresponding to the outside field. All this is only the first step in the argument.

The next step is to state that whatever total pattern of fluid flow occurs can be produced in a different way; that is, by making the flow spacing everywhere the same but by filling the iron section with a very large number of little distributed sources and sinks, appropriately differing as needed, to reproduce the total pattern. This, in theory, can be done. Whereupon, returning to electromagnetics, the iron has been replaced by air, and by an array of current filaments all parallel to the main currents.

It is now seen that Proposition 1 is merely a special form of Proposition 3.

PROPOSITION 4

It follows that Proposition 2 can also take the more general form indicated by Proposition 3. That is, the centering of round-section currents, or their redistribution otherwise in a manner symmetrical about their respective axes, can be done, even with real iron present, and the field outside a conductor boundary, in the air and in the iron, will be unchanged. Thus, Proposition 2 is seen to be a special form of Proposition 4.

REFERENCE

1. Fields From Fluid Flow Mappers, A. D. Moore. *Journal of Applied Physics*, volume 20, number 8, August 1949, pages 790–804.

Determination of Oil Temperature in Transformers

M. F. BEAVERS
MEMBER AIEE

TOP OIL* temperature and winding temperature, where the heating is caused by resistance, are determined by direct measurements when a heat run is made on a transformer in accordance with the American Standards Association Test Code for Transformers.[1] However, the average oil temperature is not directly measureable. The Test Code states that the average oil temperature may be approximated by subtracting one-half of the tank temperature gradient (as determined by measurement of the temperature at the top and bottom surfaces of the external cooling means) from the top oil temperature.

Since it is the oil immediately surrounding the windings which cools the windings, it is logical to assume that if the load on the transformer is suddenly reduced to zero, the windings will immediately begin cooling to the temperature of the surrounding oil which is effectively cooling the windings. In other words, the effective oil temperature is the temperature to which the winding is cooling at the instant of shutdown of a heat run.

It has been well established that windings cool in accordance with the general relation

$$K\theta^n dt = -C d\theta \qquad (1)$$

where θ is the temperature rise of winding over oil at any time t after start of cooling period; K denotes the heat transfer coefficient, winding-to-oil; t is the time after start of cooling, and C is the heat storage capacity of winding.

Digest of paper 50-112, "Determination of Effective Oil Temperature in a Transformer," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R.I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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* All references to oil include synthetic liquids as well as mineral transformer oil.

If a winding cools linearly as a function of the heat loss, the solution of this equation is

$$\theta = \theta_0 \epsilon^{-t/\tau} \qquad (2)$$

where θ_0 is the winding rise over oil at start of cooling period and τ is the time constant of the winding.

If a winding cools as a function of $(\text{loss})^n$, where n is any value other than 1, the solution of equation 1 is

$$\theta = \theta_0 \left[1 + (n-1)\frac{t}{B}\right]^{-\frac{1}{n-1}} \qquad (3)$$

where $B = \theta_0 C / K\theta_0^n$.

Knowing the general cooling equation of a winding and having several hot-resistance readings taken immediately after the shutdown of a continuous heat run on a transformer, the effective oil temperature and the time constant of each individual winding, as well as the winding temperature at instant of shutdown, can be determined.

Analysis of heat runs taken on several transformers of various ratings are given in Table I. The table shows that this method gives results which are within limits of test accuracy. The study also shows that the effective oil temperature for the high-voltage winding may be different from that for the low-voltage winding. However, the average oil temperature as determined from tank measurement in accordance with the Test Code is in close agreement with the average of the values determined for the high- and low-voltage windings.

REFERENCE

1. Test Code for Transformers. *Standard C57.22,* American Standards Association 1948.

Table I. Results of Analysis of Heat-Run Data

Unit	Number of Phases	Rating, Kva	Top Oil Temp, C	Effective Oil Temperature, C: High Voltage	Effective Oil Temperature, C: Low Voltage	Effective Oil Temperature, C: Avg†	Effective Oil Temperature, C: Tank**	Time Constant, Minutes: High Voltage	Time Constant, Minutes: Low Voltage	Type of Heat Run
A	3	500	67.0	61.2	61.7	61.5	62.1	9.5	10.3	S.C.*
B-1	1	75	60.8	56.8	56.0	56.4	58.9	15.8	16.8	Bucking
B-2	1	75	61.6	55.3	58.9	57.1	59.6	18.8	13.1	Bucking
C-1	1	500	68.1	63.9	61.4	62.7	64.0	5.3	7.8	Bucking
C-2	1	500	68.6	63.7	61.6	62.7	63.8	5.7	4.7	Bucking
D-1	1	167	63.0	58.2	58.0	58.1	58.2	7.3	4.6	Bucking
D-2	1	167	64.2	60.2	59.0	59.6	59.9	6.6	4.8	Bucking
E-1	1	100	65.0	59.4	58.4	58.9	59.4	11.1	5.4	Bucking
E-2	1	100	66.3	61.7	60.7	61.2	61.3	12.5	6.4	Bucking
E-1	1	100	62.9	57.8	55.0	56.4	57.2	10.4	7.4	S.C.*
E-2	1	100	63.2	57.3	57.3	57.3	57.2	11.8	6.7	S.C.*
F-1	1	333	70.1	62.0	66.8	64.4	63.4	7.7	6.3	Bucking
F-2	1	333	71.2	63.9	63.4	63.7	66.0	7.5	6.7	Bucking
G	3	300	63.5	58.7	59.2	59.0	60.0	8.2	8.7	S.C.*
H	1	200	60.2	54.4	54.0	54.2	54.4	9.2	5.9	S.C.*
I	1	500	63.5	57.8	59.7	58.8	59.2	8.2	6.0	S.C.*
J	1	200	59.5	49.9	51.5	50.7	55.0	12.4	9.1	S.C.*
K	3	75	59.3	59.7	52.4	56.1	54.9	11.6	11.5	S.C.*
L	3	75	58.1	58.6	53.3	56.0	54.0	12.4	10.1	S.C.*

* In case of short-circuit tests, top oil and effective oil temperatures were determined at end of normal current run only.

† Average of high-voltage and low-voltage values.

** Top oil temperature minus one-half the tank gradient.

Design and Test on an Electronic Exciter

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A. A. JOHNSON
MEMBER AIEE

J. E. REILLY
ASSOCIATE AIEE

IN RECENT YEARS it has been proved that synchronous generators can be operated over long periods of time without shutdown. In fact, the reliability of turbogenerators is such that more and more emphasis is being placed on getting an excitation system which approaches the reliability of the a-c generator. The electronic exciter may be one answer to the demand for improved excitation.

The electronic exciter described herein is a self-contained unit having its own source of power from the 6-phase generator which is entirely free from system disturbances. In this respect this electronic exciter is comparable to other exciter systems where direct-connected commutator exciters are used, but it is better than a separate motor-generator set where the power source to the motor is subject to system disturbance. As shown in Figure 1, excitation for the main generator is provided by a 6-phase star-connected ignitron rectifier supplied directly from a 6-phase generator connected to the shaft of the main generator to be excited. The field of the 6-phase generator is likewise excited from a small thyratron rectifier supplied from the 6-phase generator's own output. The unit is started up by flashing the field of the 6-phase generator from the station battery after which it becomes self-excited.

Ignitron tubes and electronic tubes in general have demonstrated their ability to operate continuously for long periods of time without interruption. Continuous service is further guaranteed by arranging the ignitron and thyratron tubes so that a faulty tube can be replaced without interrupting service. The ignitron tubes are paired in individual compartments and, in case of a fault on a tube, it and its companion tube are removed from the circuit. The tubes can then be grounded and removed in safety. Though two tubes are removed, the remaining four ignitrons can supply full excitation. Likewise, two or even three of the thyratron tubes can be removed without disturbing the load on the main generator.

The field voltage of the main generator is regulated by controlling the firing point of the ignitron tubes. The

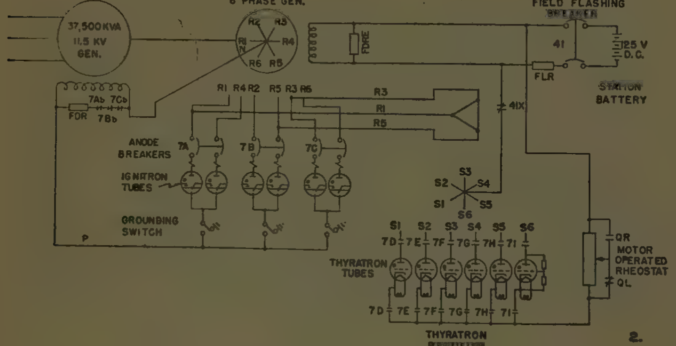

Figure 1. Electronic excitation system as in operation in the Warren Station of the Pennsylvania Electric Company

thyratron tubes fire a near-zero delay and field voltage on the 6-phase generator is regulated by a motor-driven rheostat. Both can be regulated either manually or automatically.

The output of the electronic exciter can be varied over a wide range by controlling the firing point of the ignitron tubes, and no generator rheostat is required to obtain the full operating range of field currents for the main generator. It has a high ceiling voltage and its response to a system demand for a change in excitation is practically instantaneous. Due to the time constant of the generator field, the time required for the electronic exciter to take action is of little significance since all types of regulators take action in about three cycles or less. However, the speed with which ceiling voltage is reached and the magnitude of the ceiling voltage affect the speed at which generator field current is increased. Thus, it is well suited where high speed of response is required for system transient stability. Due also to the time constant of the generator and to high-speed relays and circuit breakers, the electronic exciter will not cause higher short-circuit currents on system faults.

The 6-phase generator requires about as much space as a conventional direct-connected exciter. The ignitron tubes with their associated switchgear and controls can be located in some remote portion of the station and do not require any special foundation. The electronic exciter occupies about as much space as a motor-generator type.

The cost of the electronic exciter is higher than that of conventional direct-connected exciters because the electronic exciter has many more component parts, consisting of control transformers, tubes, control wiring, contacts, and so forth than are required by conventional excitation systems. However, it is expected that this increase in cost will be justified by better service in the form of fewer station outages due to excitation failure. Also, the cost of a spare excitation source should be considered when comparing the over-all cost of excitation facilities. No spare source of excitation is required with this type of electronic exciter since parts may be maintained or replaced with the rest of the unit in service.

Two of these units have been in operation with 37,500-kva 3,600-rpm turbogenerators in the Warren Station of the Pennsylvania Electric Company for a total operating time of 24 months. During this time, there have been no station shutdowns due to excitation failure and no tubes have had to be replaced. These two units are the only source of excitation in the plant.

Digest of paper 50-50, "Design and Test on Electronic Exciter Supplied From Common Shaft-Driven Generator," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Mechanism of the Spark Breakdown

LEON H. FISHER

The experimental data of the d-c spark discharge in air in a uniform field are reviewed in this article, and criteria for establishing the reliability of sparking potential measurements are suggested. The present concept of the mechanism of the electric spark in air is traced from the early work of Townsend to the recent streamer theory of Loeb and Meek, and Raether, and implications of recent measurements of the formative time lag of spark breakdown are discussed in detail.

THE ELECTRIC SPARK was first treated quantitatively by J. S. Townsend in 1903.[1] Since that time, the interpretation of the physical processes that lead to breakdown has been modified radically.[2–7] It is the purpose of this report to trace the development of the present concepts of the physical processes which lead to the d-c electric spark, and to discuss to what extent these processes are understood.

It will be necessary to restrict the discussion to a rather limited branch of spark breakdown, namely, the electrical breakdown in air, in a uniform field, and at pressures between atmospheric and a few centimeters of mercury.

The fact that air is the gas that forms the principal subject of the discussion needs justification. The tendency of the worker in gaseous electronics to study air is frequently criticized on the basis that air is a mixture of gases and that theoretical interpretation of experimental results is therefore of limited generality. This criticism is, to a large extent, justified. However, the large bulk of data up to now has been obtained for air. In order for a research worker to orient himself, it is often desirable to "calibrate" his equipment in air and then to extend his studies to pure gases. One must bear in mind the fact that air is the most important gas from an engineering point of view. Therefore, all statements in this article, unless otherwise indicated, refer to air.

The second restriction is that only a uniform electric field will be discussed. The uniform field is the simplest analytical condition that can be invoked and will exist for suitable electrodes. To obtain a uniform field, two parallel electrodes, properly profiled, are most often used, but sphere gaps whose radii are large compared to the electrode separation may also be employed. (Actually, the production of an accurately uniform field for spark discharge studies is an unsolved problem and will be discussed later.) We will therefore not consider to any appreciable extent the information available from the studies of the corona discharge.

The third restriction of pressure is not a rigid one and is invoked to define roughly the pressure region to be discussed. When the term "high pressure" is used, unless otherwise noted, a pressure in the neighborhood of atmospheric is meant; the term "low pressure" indicates pressures of a few centimeters of mercury and less.

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This is the second in a series of four articles; see "Gaseous-Conduction Phenomena and Their Application in Electrical Engineering" by J. D. Cobine (*EE, June '50, pp 499–504*).

The time lag measurements of L. H. Fisher and B. Bederson, which are discussed in this article, were supported by the Office of Naval Research and the Research Corporation.

THE EXPERIMENTAL DATA AND TECHNIQUES

A PAIR of properly profiled parallel electrodes between which a uniform electric field E exists is now considered. When two such plates are immersed in air, at a given pressure p and plate separation d, an electric spark will pass between the two plates at a definite difference of potential, the sparking potential, providing an adequate source of initiating ionization is present. Various authors define the spark in somewhat different ways, but for our purposes the passage of the spark may be identified by the fall of potential between the plates and by the intense emission of light. An external source of ionization is usually necessary in order for a spark to pass. The source of external ionization may be cosmic rays, radioactive material, or a source of light (usually ultraviolet) which can emit photoelectrons from the cathode. The sharpness of the sparking potential in clean, dry air (when an external source of ionization is present) is often underestimated. Recent measurements have shown that the sparking potential in clean, dry air is sharp to at least several volts,[8] and in the opinion of the author, the sparking potential is more definite than the stability of existing high-voltage power supplies. If there is some lack of definiteness in the potential at which sparks occur, it is probably less than one-tenth of a volt.

The chemical action of successive sparks may, in limited gas volumes, produce chemical changes which alter the sparking potential.[9] The sparks produce oxides of nitrogen which lower the sparking potential. This effect can be avoided by limiting the chemical action by a sufficiently large current-limiting resistor and by using a discharge chamber of large volume.

When an ionization chamber is evacuated and subsequently filled with clean, dry air, the sparking potential gradually rises as each successive spark occurs until about 50 sparks have passed, at which time the sparking potential becomes constant. This constant sparking potential should be taken as the experimentally observed sparking potential. This effect of gradually increasing sparking potential is probably associated with the removal of small dust particles from the electrodes. As the sparking potential increases,

the size of the remaining particles increases, until all dust particles are removed. There does not seem to be any other way of processing the electrodes so that seasoning by sparks does not take place. After the seasoning process, the sparking potential becomes quite sharp, provided the air is dry. For moist air the scattering of the sparking potential is quite pronounced, but it is not as pronounced as with the electrodes exposed to the open atmosphere.[10] The moisture effect persists after repeated sparking and is probably due to the continual evaporation and condensation of water vapor on the electrodes. The practice of studying sparking potentials in the open atmosphere, while of great importance from an engineering point of view, does not lead to accurate determinations of sparking potentials. Usually the sparking potential reported in such engineering studies is the average of many measurements, whereas the physically significant value is probably the highest value measured.

The appearance of the spark is filamentary at pressures from atmospheric down to about 20 centimeters of mercury (at a plate distance of one centimeter). Below this pressure the spark gradually becomes more diffuse, finally covering the entire area of the electrodes. This diffuse spark is the beginning of a glow discharge, although the conventional glow discharge is one in which the length of the discharge is much greater than the diameter of the plates. In the intermediate pressure region, between the filamentary and the diffuse spark, the discharge changes gradually from one form to the other. In the transition region, widely separated bright spots appear on the cathode. These bright spots may also be observed on the cathode of a conventional glow discharge.

The most widely studied parameter of spark discharge is the sparking potential. Although sparking potentials have been measured for about 90 years, starting with the work of Kelvin, the agreement among various observers has not been too satisfactory. For the experimental values of the sparking potentials one may refer to the compendium of results given by Schumann,[11] the bibliography listed by Strigel,[12] and the recent measurements of Fisher.[10] Agreement among observers to within several per cent is to be considered as excellent agreement; usually the deviations are much larger.

The failure to provide adequate triggering electrons to initiate the discharge in a reasonable time, the absence of humidity control, the neglect of the effect of dust particles, and the difficulty of accurate measurement of high voltage have given rise in the past to uncertainties in the experimental values, but these effects can be eliminated easily.

There are, however, a series of effects which cannot be eliminated without difficulty, and must be discussed. These are the effects of the diameter of the plates, the electrode profiles, and the inductive action of surrounding conductors. The important parameter in the diameter effect is the ratio of the gap width to the electrode diameter. The smaller this ratio, the more uniform will be the field between the plates. An attempt is often made to eliminate the effect of the electrode profiles by the use of electrodes profiled according to the calculations of Rogowski.[13] Grounding the conductors adjacent to the electrodes is generally considered to bring the inductive action of the surrounding electrodes under control.

Actually, no one knows the proper ratio of plate separation to electrode diameter to make the field between the plates uniform to a prescribed accuracy in magnitude and direction (this ratio is dependent on profile shape also); Rogowski's calculations of electrode profiles are for two dimensions only, and hence cannot be applied to the case of actual electrodes; grounding conductors adjacent to the electrodes may make measurements reproducible, but one must not mistake reproducibility for absolute measurements of sparking potentials in uniform fields.

One may attempt to determine the magnitude of all three troublesome effects at once by the use of a cross-sectional electrolytic model study. These electrolytic model studies are not satisfactory because the cross-sectional model solves the electrostatic problem in two dimensions instead of in three.

With the previous comments in mind, it would seem reasonable to assume that there does not exist a single set of measurements of sparking potentials over any appreciable range of pressure and gap width whose absolute accuracy is known, nor is there any indication that such a set will be available in the near future.

One should establish a set of criteria for determining the reliability of sparking potential measurements. Even though it is impossible to fulfill all the requirements, it is desirable to set forth an ideal for which to strive. One may require that the following items not affect the measurements: improving the profile of the electrodes, increasing the diameter of the plates for a given gap separation, and increasing the diameter of the chamber. Such a set of measurements made over a wide range of pressures and plate separations is needed. Thus, present values of the sparking potential do not give one too severe a quantitative criterion for a theory to satisfy. As will be seen, the leading term in any quantitative theory of spark discharge is an exponential term whose exponent is a rapidly varying function of field strength and pressure. Thus from the present sparking potential data alone, one cannot infer too much about the physical processes which occur.

One regularity about sparking potential measurements which has been commonly accepted is Paschen's law, discovered experimentally in 1889.[14] This law states that the sparking potential is a function of the product pd (strictly speaking ρd, where ρ is the gas density). Although this law has been accepted for many years, and although it has been verified over a limited range, it has never been subjected to a rigorous experimental test. The law is not one which is satisfied by modern theories of spark discharge. There is, in fact, some experimental evidence that Paschen's law does not hold at extremely high pressures (above atmospheric),[15] but just how reliable the measurements are in view of the criteria set up in the foregoing is unknown.

One may mention something about the effect of the electrode material. Theoretically, if electrode material has any influence on the sparking potential, the effect should be confined largely to the cathode. The usual statement made concerning this point is that the sparking potential near atmospheric pressure is independent of the cathode material.

THE PHYSICAL PROCESSES AT WORK

The fundamental processes operating to cause electric breakdown are now considered. If the potential difference across a gap is raised gradually, there is a current through the gap which increases at first, remains essentially constant for a large voltage range, and then at a definite potential (the potential depending on p and d) increases rapidly until a spark occurs. The discharge below breakdown appears dark to the eye and proceeds only as long as a primary source of ionization is maintained. Thus such a discharge is called a non-self-sustaining one. The current-voltage curve for a constant primary ionization is indicated in Figure 1 for a pressure of 760 millimeters of mercury and a plate separation of one centimeter. Actually the graph shows current amplification as a function of voltage for the important voltage region. By gas amplification is meant the factor by which the constant primary source of current is multiplied. It is the explanation of breakdown in terms of the currents below breakdown that constitutes the theory of the d-c spark.

Townsend was first to measure systematically the currents in a gap below breakdown. He showed that the currents above the plateau could be explained if one assumes that an electron is capable of ionizing neutral gas molecules in the gap. The current may be initiated by the liberation of an electron from the cathode by the photoelectric effect. This electron then starts on its way toward the anode under the influence of the electric field, the electron gaining energy from the field between collisions of the electrons with the neutral gas molecules. When an electron collides with a neutral molecule, it may have either an elastic or an inelastic collision. If the energy of the electron is low, the electron will lose a negligible amount of energy in the collision and will continue on the average to gain energy from the field after the collision. The energy loss in an elastic collision is small because of the very high ratio of the masses of molecules to electrons. Thus the electron energy may become appreciable, and if the energy of the electron is high enough, the electron will transfer a large share of its energy to the neutral molecule, raising the molecule to an excited state. If the electron energy is even higher, the electron may ionize the neutral molecule leaving an additional electron and a positive ion. Then two electrons are available for further ionization, and the number of new electrons created in a small distance dx increases as the location of dx approaches the anode. To be more explicit, the number of new electrons dn created per unit time in a distance dx in the field direction is proportional to n, the number of electrons per unit time crossing a plane parallel to the electrodes a distance x from the cathode, and to dx. That is

$$dn = \alpha n \, dx \qquad (1)$$

where α is a proportionality factor, now called the first Townsend coefficient. If n and dx are unity, then $dn = \alpha$, and one sees that α represents the number of new electrons created by a single electron in traveling unit distance in the field direction. This concept of ionization by collision was one of the great contributions of Townsend to the field. Townsend found experimentally that α/p is a function of the ratio of field strength to pressure E/p. That α/p should be a function of E/p is reasonable as can be seen from the following rough consideration. The electron mean free path λ is inversely proportional to p, and thus α/p is a measue of $\alpha\lambda$, the number of new electrons created by a single electron per mean free path in the direction of the field. Similarly E/p is a measure of $E\lambda$, which, when multiplied by the charge of the electron, is the energy gained by an electron in traveling a mean free path in the field direction. Thus the functional dependence of α/p on E/p means that the number of new electrons created by an electron in traveling a given distance in the field direction depends on the average gain in energy of the electron in traveling the same distance in the field direction. In order to calculate values of α from experimental measurements, one must write equation 1 in integral form. Assuming α to be a constant, one obtains

$$n = n_0 \epsilon^{\alpha x} \qquad (2)$$

where n_0 is the number of electrons liberated from the cathode per unit time by the external source of ionization. Multiplying equation 2 by the charge of the electron, one obtains the electron current i_- as

$$i_- = i_0 \epsilon^{\alpha x} \qquad (3)$$

where i_0 is the primary electron current at the cathode. Since there is no positive-ion current at the anode, the entire current i through the gap is

$$i = i_0 \epsilon^{\alpha d} \qquad (4)$$

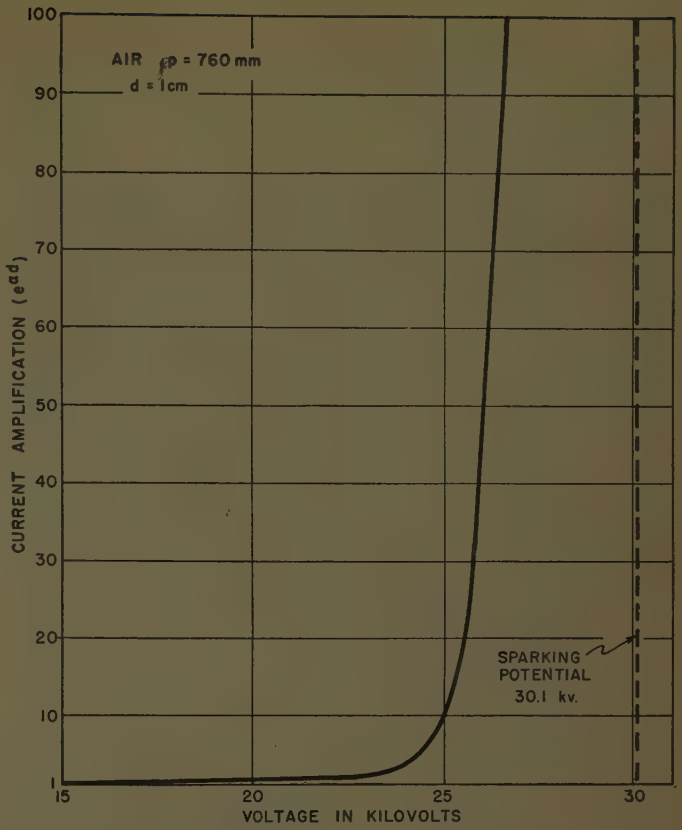

Figure 1. Current amplification versus voltage for a 1-centimeter plane parallel gap in air at atmospheric pressure. To obtain the current through the gap, the initial photoelectric current from the cathode is multiplied by the current amplification

Hence, by measuring currents at various gap widths at constant E/p, values of α may be calculated. The fact that for a large number of gases, over a wide range of variables, equation 4 leads to a consistent description of the experimental results gives us confidence in the derivation. In addition to this quantitative agreement, we have evidence that the concept of ionization by collision is in harmony with our knowledge of atomic physics. The single primary electron and its products are called an electron avalanche. An electron avalanche alone, however, does not constitute breakdown, since breakdown marks the onset of a self-sustained discharge.

Townsend found, however, that at low pressures, equation 4 is incapable of describing the currents very close to breakdown, and that the current rises even more rapidly than is predicted by the equation. Townsend ascribed this additional current to the production of new electrons by some other mechanism than the primary process outlined and introduced a second coefficient β now called the second Townsend coefficient. (Usually one uses a quantity $\gamma = \beta/\alpha$ more frequently than β.) Townsend assumed that β represents the number of secondary electrons produced by a single positive ion in traveling unit distance in the field direction toward the cathode. These secondary electrons, according to Townsend, are produced by the collision of positive ions with neutral gas molecules. Because of the large mass of the positive ion, it would lose a large fraction of its energy in elastic collisions, and thus it is more difficult for a positive ion to reach a given energy than it is for an electron. Quite aside from this point, however, positive ions require much larger energies than they have in a discharge in order to produce ionization by collision in the gas. Direct experiments have shown that it is necessary to look elsewhere for the proper secondary mechanism.*

We may nevertheless discuss the equation which Townsend[1] derived for the current i below breakdown, namely,

$$i = \frac{i_0(\alpha - \beta)\epsilon^{(\alpha-\beta)d}}{\alpha - \beta\epsilon^{(\alpha-\beta)d}} \tag{5}$$

This equation describes the dark-current data satisfactorily (provided the primary current density is not too high), a fact which led Townsend and others to have confidence in the mechanism of ionization by positive ions in the gas. As has been shown,[16] several other physically acceptable secondary processes give nearly the same analytical form as equation 5, but we postpone consideration of these alternate mechanisms for the time being.

Townsend noticed that if

$$\alpha = \beta\epsilon^{(\alpha-\beta)d} \tag{6}$$

then the current between the plates is infinite, and this was taken by Townsend as the condition for a spark. Infinite currents do not occur in nature, and one may say that the steady-state equation 6 is meaningless when the denominator becomes zero. Physically what happens is that the current grows to a large value (perhaps of the order of microamperes) until there is so much ionization in the gap that intense local space-charge fields build up. These space-charge fields give effective values of the field locally far in excess of the value obtained by dividing the potential difference between the plates by the plate separation, and hence these fields lead to more and more intense ionization, and the gap breaks down. This autocatalytic process cannot be described by equation 6, but the current up to the time that the explosive process occurs is physically describable by such an equation. The vanishing of the denominator of equation 6 then marks the threshold condition for the occurrence of the spark. To emphasize the difference between the steady-state and transient conditions, one may point out that in spite of the fact that most of the positive ions are created in a very small region near the anode, the maximum positive ion density in the steady state is in a small region near the cathode. In a transient phenomenon, however, one may expect explosive effects to originate in the anode region before the positive ions have had a chance to move.

* For a complete discussion of this point see reference 2, page 374.

Equation 6 can be checked with the experimentally observed sparking potential measurements, and reasonable agreement between the value of the sparking potential and the corresponding experimentally determined values of α and β has been obtained at low pressures. With the recognition of the impossibility of secondary ionization by positive ion bombardment of neutral gas molecules under ordinary sparking conditions, one found it necessary to invoke other secondary mechanisms. The first alternate process to be considered was the emission of secondary electrons by positive ion bombardment of the cathode. This alternate mechanism called for a reinterpretation of β, but other than that, no serious change was made in the theory. If one uses the definition of γ and uses the experimental fact that α is much greater than β, equation 6 gives as the threshold condition for a spark

$$\gamma\epsilon^{\alpha d} = 1. \tag{7}$$

If one interprets γ as the number of secondary electrons liberated at the cathode by one incoming positive ion, equation 7 gives the condition that a single electron should start a self-sustained discharge (since $\epsilon^{\alpha d}$ positive ions are formed by one electron). Since, to a high degree of approximation, equations 6 and 7 are mathematically equivalent, one equation is just as good as the other in fitting the sparking potential measurements. One begins to realize then why sparking potentials are of little help in deciding the nature of the physical processes leading to the spark. A self-sustained discharge, maintained by positive ion bombardment of the cathode, is what is at present called the Townsend mechanism of the spark.*†

In the past, people have applied the Townsend theory to atmospheric pressure. There are several objections to this procedure. The first difficulty is that the sparking potential seems to be independent of cathode material at pressures near atmospheric, whereas the Townsend mech-

* An alternate mechanism in which secondary electrons are emitted from the cathode by electromagnetic radiation produced in the avalanche has in the past not been considered to be effective, but this process may play an important role at lower pressures. (The cathode spots referred to earlier in the article are very likely photoelectric in origin.)

† Recent measurements indicate that for voltages a few per cent above breakdown, the Townsend mechanism does not hold down to pressures as low as a few centimeters. See references 7, 17–20. For the purposes of the historical development, we will not consider these results for the present.

anism calls for a dependence on cathode material. However, detection of this effect might prove difficult experimentally. A second difficulty is that no β (or γ) has ever been observed at pressures near atmospheric. Whether the failure to observe β at higher pressures is instrumental or not, is, in the opinion of the writer, still an open question. It is the opinion of the author that one should be able to detect a departure from equation 4 at all pressures below breakdown, if power supplies were sufficiently well regulated. The potential region where β is measurable at high pressures may be very narrow.*† However, the most serious objection to the Townsend theory came from the study of the formative time lags of spark breakdown; this difficulty will be discussed in detail.

The formative time lag is defined as the time necessary for a potential to be maintained across a gap before it breaks down, provided a primary source of ionization is present. Thus the primary processes leading to a spark take time to build up, and from mobility measurements one knows that at the sparking potential, the positive ion requires about 18 microseconds to cross a 1-centimeter gap at atmospheric pressure. In 1936, Schade[22] measured formative time lags in neon at very low pressures and found that the time lags were of the order of ten microseconds and greater. Schade could not measure times shorter than ten microseconds with his equipment, a circumstance of some importance in the subsequent theoretical development. But even earlier, beginning in about 1928,[23–27] there had been observed a formative time lag of spark breakdown in air near atmospheric pressure which was so short that the positive ions could not possibly have had time to cross the gap.** These times were found to be of the order of 10^{-7} second, some observers reporting formative times as short as 10^{-9} second. Thus the Townsend theory was shown to be inadequate at pressures near atmospheric, and a new theory, now called the streamer theory, was developed almost simultaneously by Loeb and Meek, working together, and by Raether for this pressure region. The general impression, with the enormous prestige of the Townsend theory and the confirming work of Schade, was that the Townsend theory is valid at low pressures and that the streamer theory applies at high pressures.

Loeb developed the streamer theory on a qualitative basis by an analysis of positive point-to-plane corona studies, and Raether developed his ideas by a study of inhibited spark discharges in a cloud chamber. Since the streamer theory is of such vital importance in discussing spark discharge work, it is necessary to discuss it in some detail. The streamer theory takes into account the short formative time lags observed in spark breakdown, and the theory invokes formative times of the order of electron transit times. The streamer theory assumes that there is photoionization in the gas.‡ The photons which give rise to photoionization are formed in the electron avalanche, since the primary electron and the resulting electrons in the avalanche produce in traveling toward the anode, in addition to ionization, molecules in excited states. When these excited molecules return to their ground state, the photons emitted may be capable of photoelectrically ionizing other components of the gas whose ionizing potentials are less than the excitation potential of the photon-producing molecule. The role of photoionization in a pure gas (without metastable states) is not so simple to imagine, but since the discussion is restricted to air, this point need not be discussed further. These photons are produced largely in the neighborhood of the anode, and when absorbed in the gas produce photoelectrons. At very low pressures, photoelectrons may even be liberated at the cathode, but it is commonly believed that down to very low pressures the photoelectrons are formed very close to the relatively immobile positive space charge. The photoelectrons which are on the cathode side of the positive space charge are now in an electric field which is the vector sum of the applied field and the field due to the positive space charge. These photoelectrons are thus in an enhanced field, which not only enables these electrons to ionize by collision to a far greater extent than if the field were not distorted, but the direction of the field is such as to produce an extension of the positive ion space charge toward the cathode with no motion of the positive ions. When the density of positive ions at the cathode reaches a sufficiently high value, practically the entire potential drop between the electrodes exists between the cathode and the neighboring positive space charge. This large potential drop in a short distance gives rise to an enormous field near the cathode, and emission of an intense spray of electrons from the cathode results. This stream of electrons traveling up the streamer channel constitutes the breakdown. One should notice that the streamer mechanism is a transient phenomenon.

The first attempt to put the streamer mechanism on a quantitative basis was made by Meek, who suggested that a streamer would occur if the space charge field of the positive ions at the anode is equal to the applied field. (Raether later suggested a similar criterion.) The consequences of this criterion were developed into an equation for calculating sparking potentials, which is now called Meek's equation. Actually, Meek found that if he assumed that a streamer occurs if the positive ion space charge field at the anode is one-tenth of the applied field, better agreement with experimentally observed sparking potentials is obtained. Meek calculated sparking potentials from his equation and found that he obtained good agreement with the measured sparking potentials in air down to $pd=200$ millimeters of mercury $\times$ centimeters. At this value of pd, Meek's equation gave results which are too high, the departure increasing with decreasing pd. Meek then suggested that $pd=200$ millimeters of mercury $\times$ centimeters is the point at which the streamer mechanism fails and the point at which the Townsend mechanism applies. This conclusion was further supported by the short formative time lags observed at high pressures and the long times observed by Schade in neon. It was later pointed out,[31,32] however, that while Meek realized that his equation did

*In trying to observe deviations from equation 4, one must be on guard to avoid space charge effects. See reference 21.

† It is interesting to note, in passing, that we do not yet understand why β drops so suddenly to such small values at high pressures and low values of E/p.

** For a complete bibliography up to 1941 see reference 4, page 32.

‡ Unfortunately, there is very little experimental information on this point. Usually the methods used are indirect, and often the gas studied was not air. For information available on this point up to 1941, see reference 4, page 37, and for information on more recent work see references 28–30.

not satisfy Paschen's law, he did not realize that the departure of his equation from experiment at $pd = 200$ millimeters of mercury × centimeters was determined by the fact that he had made his calculations for a single particular plate distance (one centimeter) and had varied the pressure. Had Meek used a constant pressure of one atmosphere and a varying plate distance, he would have found satisfactory agreement down to values of pd much below 200 millimeters of mercury × centimeters. Thus, if there is a deviation of Meek's equation from experiment at low pressures, the value of pd at which a deviation sets in should be a function of pressure and plate distance separately. As has already been stated, the present experimental data do not adequately test Paschen's law; we may now add that the present experimental data do not supply an adequate test of Meek's equation either.

One may digress to discuss the use of Meek's equation. It is not clear, at present, that calculations with Meek's equation are any more satisfactory in representing the experimental sparking potential data than is an equation like 6 or 7. As a matter of fact, if instead of using Meek's equation, one assumes that a spark will occur when the density of positive ions at the anode reaches a certain value, good agreement is obtained with experiment. Even setting the total number of ions in an avalanche as a definite number gives satisfactory agreement. In all of these quantitative formulations, the specific mechanism is masked by the appearance of the same term, $\epsilon^{\alpha d}$ in all of the equations. Since α/p is itself a rapidly varying function of E/p, small variations in the assumed value of the sparking potential mask the other terms depending on the particular mechanism assumed. It is to be noticed that Meek's equation assumes that the production of photoelectrons is adequate, but does not take this effect into account quantitatively. Recently, Loeb[33] has attempted to improve the criterion for streamer formation by including the photoelectric effect quantitatively, but at present, no adequate data exist for testing the resulting equation.

The streamer theory has proved very fruitful in stimulating further research, and one may consider the theory as an important milestone on the way to a fuller understanding of the complex phenomenon of the spark.

With the points made here in mind, a research program at New York University sponsored by the Office of Naval Research and the Research Corporation was undertaken. This program was started to determine whether a systematic study of formative time lags could be used as a better device than experimentally observed sparking potentials for understanding the mechanism of the spark. In all probability, sparking potential measurements will not be improved radically in the near future. The principal aim of the research was to determine the value of the pressure and plate distance at which the transition between streamer and Townsend mechanism occurs by the measurement of the formative time lags at small overvoltages. (Per cent overvoltage is defined as $(V - V_s)\,100/V_s$, where V_s is the sparking potential and V is the applied potential.) These experiments show that, at all pressures from atmospheric down to a few centimeters, formative time lags of spark breakdown in air are short (a fraction of a microsecond) at small overvoltages of the order of a few per cent, and that below this value of overvoltage, the formative time lags are very long and may be as long as a hundred microseconds. Earlier measurements of formative time lags were all made (with the exception of Schade's work) at overvoltages of at least two per cent and usually at much greater values. Thus one sees that the streamer theory as outlined here must be modified in the neighborhood of the threshold voltage, and that the Townsend theory must be re-examined at low pressures and high overvoltages. The long formative times mean that one must invoke the action of positive ions as an effective agent in causing breakdown near the threshold. The positive ions, however, cannot be effective by the liberation of electrons at the cathode, or else the smooth transition from long formative times at low overvoltages to the short times at higher overvoltages would not be observed. The dependence of the time lags on plate separation and pressure lead, from a theoretical analysis, to the same conclusion. Rather, one has to look for another effect, and the proper effect is the distortion of the field near the cathode by the positive ions in the gap.[34] As these positive ions move toward the cathode, the field distortion makes the field increase even more at the cathode, the effect increasing continuously as the positive ions approach the cathode. This increased field increases the value of α locally in the neighborhood of the cathode, and acts as an effective secondary process.[21] As the overvoltage is increased, the positive ions have to move a shorter distance toward the cathode to produce the same field distortion caused at lower overvoltages. As the overvoltage is increased further, the electron avalanche need not travel across the entire gap before an adequate space charge builds up. Whether the Townsend mechanism holds at very low pressures is a question that should be reopened. The short time lags observed at low pressure and at appreciable overvoltages may be due to photoelectric action in the gas or at the cathode. This is also a question that must be investigated.

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Military Storage Batteries

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Important improvements in the performance of military storage batteries, particularly at low temperatures, has been in progress for some time. This article* describes some of the recent developments, with particular emphasis on lead-acid and nickel-cadmium batteries.

MILITARY NEEDS and planning call for operation at extreme temperatures of a wide variety of equipments; communication, vehicular, and others which are dependent on storage batteries for electric power. During World War II it was realized that subzero temperature operation of storage batteries posed a more formidable problem than high-temperature operation. This was true even though the lower temperature limit set at that time was only −40 degrees Fahrenheit. At the end of the war, however, temperature limits were further extended so that subzero operation became even more difficult.

It is evident that the activity of a storage battery, as a function of temperature, is seriously affected at the extremely low temperatures specified for the operation of military equipment. To overcome the difficulties which were known to exist, a research and development program was established for the improvement of the performance of storage batteries under all conditions but particularly at low temperatures. This program which has been in progress for some time was planned and directed by the Signal Corps Engineering Laboratories and has involved the services of industry, the universities, and other research and development organizations. As a result of this work, important improvements have been effected in the high-rate low-temperature discharge characteristics of the lead-acid battery and impressive beginnings have been made in the field of alkaline nickel-cadmium secondary batteries.

As a starting point for the investigation of the performance of the lead-acid battery at subzero temperatures, there was available some published information and data and the experience of the manufacturers accumulated during World War II in the production of batteries that would give some operation down to −40 degrees Fahrenheit. In addition, the Signal Corps Engineering Laboratories had the benefit of test data gathered over a period of four to five years on the testing of electrolyte-retaining and free-electrolyte-type lead-acid batteries. It might be said, at this point, that the digest of all this formed the basis for the preparation of the specification presently in use at the Signal Corps Engineering Laboratories and designated as United States Army Specification 70-400 for portable lead-acid storage batteries. What could be expected from lead-acid batteries at the time the first issue of the specification was prepared in 1945 is indicated by the requirements for Signal Corps Battery *BB-221/U*, a *2H* type in the nomenclature of

* Second in a series of three articles on batteries. The first was "Primary Batteries," C. H. Clark (*EE, Jun '50, pp 515–18*).

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the Society of Automotive Engineers. These requirements were 4.75 minutes of discharge at 300 amperes at 0 degrees Fahrenheit with a 5-second voltage of 4.4 volts and 30 ampere-hours at −40 degrees Fahrenheit at the 20-hour rate.

The experimental work performed by the industry was based for the most part on a cognizance of those factors which affect the internal resistance of the battery and the modification of these factors by changes in engineering design to bring about a reduction of this internal resistance. The effect of current density on material utilization was also borne in mind and attempts were made to increase effective surface areas to optimum values. In conducting these studies, use was made of *1M* and *2H* type lead-acid batteries, generally rated at the 20-hour rate at 90 and 120 ampere-hours respectively. It was hoped that results obtained could be applied to batteries of other sizes.

During 1946 and 1947 an attempt was made to effect specific and quantitative improvements in the low-temperature characteristics of Signal Corps standard lead-acid batteries. An examination made of a large number of oxides to determine which was most effective in improving low-temperature high-rate capacity led to the conclusion that through mix variance the cranking capacity could be improved as much as 23 per cent and the best formulations for positive and negative pastes made use of fine sublimed oxides. Though these mixes improved capacity, they failed to improve the 5-second voltage, and it was found that an increase in the 5-second voltage was dependent upon the type of interplate insulation used and the plate surface area. Through the use of thin microporous rubber separators or plastic styron separators, and by increasing the number of plates per cell from 17 to 23, substantial improvements in the 5-second voltage were effected. This work led to the construction of batteries using an increased number of thinner plates pasted with highly active oxides and assembled with thin microporous rubber separators. Such cell assemblies showed a 56-per cent improvement in cranking time and a 12-per cent improvement in 5-second voltage over specification requirements for a 300-ampere discharge at 0 degrees Fahrenheit, and gave relatively high capacities at −40 degrees Fahrenheit. However, at −65 degrees Fahrenheit no capacity at useful voltage was available under conditions of high-rate discharge.

During the last two years, the development program covering the low-temperature operation of the lead-acid battery was extended. Plates as thin as 0.052 inch and separators as thin as 0.017 inch, were prepared. Numerous negative expander materials were investigated and several which materially improve subzero capacities at high rates of discharge were developed. New case material and case fabrication techniques were utilized permitting the construction of batteries having greater internal volume through the use of thinner container walls without sacrificing mechanical strength. The effect of previous history on low temperature performance was examined and it was found that 0-degree-Fahrenheit cycling (charging and discharging) improved subsequent low-temperature performance as much as 50 per cent. Optimum acid to active-material ratios and optimum electrolyte concentrations for subzero temperatures were determined. Batteries were constructed to give cranking capacities at −40 degrees Fahrenheit in excess of present specification requirements for 0 degrees Fahrenheit. These batteries also gave substantial capacities at −65 degrees Fahrenheit with voltages high enough to be useful in cranking or other high-rate applications.

Though, in the course of the work of the past few years, experimental *2H* size batteries were constructed with as many as 39 plates utilizing separators as thin as 0.017 inch, it was concluded that the preferred construction at this time should have only 27 plates, each 0.062-inch thick, separated by interplate insulation 0.047-inch thick (0.020-inch back web and 0.027-inch rib). Such a design exhibited good acid to active material balance, satisfactory life characteristics, and extended the improvements in cranking time and 5-second voltage from 56 to 127 per cent and from 12 to 17.5 per cent respectively.

While the foregoing investigations of the lead-acid battery were being conducted by the industry under the direction of the Signal Corps Engineering Laboratories, studies of a more fundamental nature were in progress at universities and research organizations. Through the use of X-ray and electron microscope equipment and other experimental facilities, an attempt was made to determine the physical and chemical differences existing in lead-acid batteries operated at normal temperatures and those operated at subzero temperatures, down to −65 degrees Fahrenheit. It was believed that if marked differences were observable, the reduced performance at −65 degrees Fahrenheit could be explained in terms of these differences. However, during these studies, no new compounds or reactions were reported, but changes in physical state were observed.

It was concluded quite early in these investigations that the negative plate would be most limiting in low-temperature operation of the lead-acid battery and, therefore, attention was concentrated on this electrode although the behavior of the positive plates was also examined. The discharge characteristics of different type negative plates were studied at various temperatures. At subzero temperatures, the available capacity was more closely related to previous history effects than to the composition based on oxide and expander formula. Previous charge and discharge temperatures were found to be of paramount importance in influencing the discharge and charge characteristics of negative plates at −65 degrees Fahrenheit.

As indicated earlier, the occurrence of no new compounds or reactions at subzero temperatures was reported. However, the existence of fine lead and lead-sulfate crystals and of a distorted, highly active structure following 0-degree-Fahrenheit cycling of negative plates was evident, and in terms of these the heightened activity and improved performance of the negative plate during discharge and charge at −65 degrees Fahrenheit was explained.

Since it appeared that the physical condition of the negative plate was of extreme importance in subzero operation, attempts were made to develop new and improved organic expander materials to increase and maintain plate porosity and available surface area. Efforts were made also to determine those chemical entities in the expander structure which make it active and it was concluded that the presence of free hydroxyl groups was necessary for proper ex-

pander functioning. It was found that compound formation which tied up the free hydroxyl groups in the expander material reduced expander activity.

It appears that good progress has been made during recent years in the development of lead-acid batteries for low-temperature operation and in the determination of some of the factors which affect such operation. Perhaps the most outstanding has been the effect of 0-degree-Fahrenheit cycling on −65-degree-Fahrenheit performance, and the development of the new case material which makes possible an increase in the internal volume of an automotive-type lead-acid battery without alteration of the external dimensions. The combination of these developments plus the progress made in achieving a balance of a large number of thin plates pasted with fine oxides and more active expanders, combined with low-resistance separators, has made possible the construction of lead-acid batteries capable of giving discharge capacities at subzero temperatures down to −65 degrees Fahrenheit far in excess of anything previously available. These developments in lead-acid battery engineering are gradually being incorporated in batteries manufactured for military applications and revised procurement specifications will be set up soon.

Turning now to the nickel-cadmium alkaline storage battery, it should be pointed out that this battery may be built with plates in three basic constructions, the tubular, the flat pocket, and the sintered-plate types. In each construction, the negative active material is cadmium and the positive active material is composed of oxides of nickel. In the sintered-plate construction, the most recently developed in the nickel-cadmium battery field, the plate is made by sintering nickel powder into a highly porous mass, about 80-per cent porosity, referred to as the plaque, which is then impregnated with the active materials. It is this construction that is most promising and on which development and research activity is being concentrated. The sintered-plate nickel-cadmium battery is a development of the past 15 years, the initial work having been started in the laboratories of the I. G. Farben Industrie Aktiengesellschaft, where the possibility of sintering carbonyl nickel powder, prepared by the thermal decomposition of nickel carbonyl, into a highly porous and conducting mass was recognized. Such a construction favored an increase in capacity per unit weight and volume without the sacrifice of such other valuable characteristics of the nickel-cadmium battery as high retention of charge, ability to stand for long periods of time in a discharged condition without deterioration, ruggedness, and ability to deliver substantial capacities at high rates of discharge. In addition, it appears possible to charge this type of battery at usual rates with good efficiency at temperatures as low as −40 degrees Fahrenheit.

On undertaking the work on sintered-plate nickel-cadmium batteries in this country, a major problem was encountered in that there was no domestic source of carbonyl nickel, the material used in Germany for the manufacture of the sintered plaque. This material, it should be stated, has physical characteristics which make it peculiarly suitable for sintering highly porous, low-density plaques with good mechanical strength. Electron microscopy and particle size distribution studies of German carbonyl-nickel powder made possible the characterization of this material and provided the basis for the evaluation of a large number of nickel powders which were examined to determine their suitability for the preparation of the plaques for sintered plates. Eventually, as the result of a closely co-ordinated effort between the Signal Corps Engineering Laboratories and the Mond Nickel Company of England, a nickel powder having good sintering characteristics was developed by the Mond Nickel Company. Though it was felt that this source of supply would be satisfactory under normal conditions, it was believed that a domestic process for the preparation of carbonyl nickel should be developed. With this in mind, development work was undertaken by one of the members of industry engaged in the study of the sintered-plate battery, under the direction of the Signal Corps Engineering Laboratories, to develop a laboratory pilot plant for the preparation of carbonyl nickel from nickel carbonyl. As a result of these studies, a satisfactory process has been devised which can be adapted for large-scale production.

In addition to the development of a domestic process for the manufacture of carbonyl nickel, considerable time and study have been devoted to the development of optimum sintering techniques and to the improvement and simplification of the impregnation procedures involved in the fabrication of sintered plates. As in the case of the lead-acid battery, the construction of sintered-plate nickel-cadmium batteries with thinner plates spaced closely together makes possible the discharge of this type of battery at high rates and subzero temperatures. Discharges conducted at an apparent current density as high as 0.6 ampere per square inch have been possible with a material utilization of the positive active material as high as 85 per cent.

As has been shown, considerable advance has been made since the close of World War II on the development of lead-acid batteries for low-temperature operation without sacrificing other operating characteristics. In addition, important beginnings have been made in the investigation of the nickel-cadmium battery and the possibility of adapting this battery for military use now seems fairly well assured. However, the progress made to date in the field of military storage batteries, both lead-acid and nickel-cadmium points the way towards the need for further study. An X-ray program for the basic study of lead oxides is under way and it is expected that this work will provide additional information regarding the changes occurring in the active materials in the lead-acid battery during the preparation of battery oxides, during the use of these oxides in the processing and conditioning of the battery, and during battery operation including charge, discharge, and storage over a wide range of temperatures. The problem of charging the lead-acid battery efficiently at subzero temperatures is also being investigated and this may lead to a further study of expander materials, since the effect of these materials on the physical characteristics of the negative plate appears, at this time, to be directly correlated with negative-plate activity and battery performance, chiefly at subzero temperatures.

The development of the sintered-plate nickel-cadmium battery has progressed substantially, and sufficient information and data have been accumulated to warrant the setting up of production facilities on a small scale in a pilot plant.

Power Measurement by the Hook-On Method

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THE hook-on method is here defined as the measurement of an electrical quantity, where the current component of such measurement is obtained by encirclement of the current-carrying conductor by a removable magnetic structure. This magnetic structure is thereby subjected to a magnetomotive force, which is a unique function of the current and provides a magnetic flux for a secondary winding or an instrument mechanism. Available self-contained instruments are limited to current measurement. Interest in extending this measurement method to active and reactive power has resulted in the development of the self-contained hook-on wattmeter, illustrated in Figure 1. It was necessary that this instrument meet exacting requirements as to weight, simplicity of operation, and range of full-scale capacities (3 to 300 kw).

Since power measurements involve circuits which will preserve phase-angle relationships, it was evident that a direct application of ammeter magnetic circuits would not necessarily be satisfactory. The preferred construction consists of a ferrodynamic wattmeter, the field of which is energized by the current-carrying conductor through the hook, shown in Figure 2. By making this field linear with respect to current through the hook, and by using a spring-controlled moving system, the scale capacity is directly proportional to the potential circuit resistance. Range changing is accomplished, therefore, by potential switching alone.

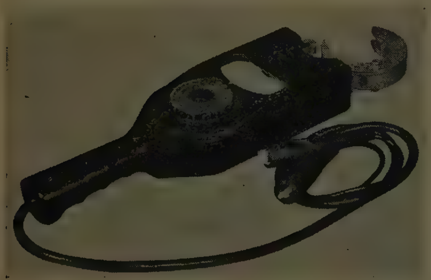

Figure 1. Portable hook-on wattmeter with single-knob switching for six ranges from 3 to 300 kw

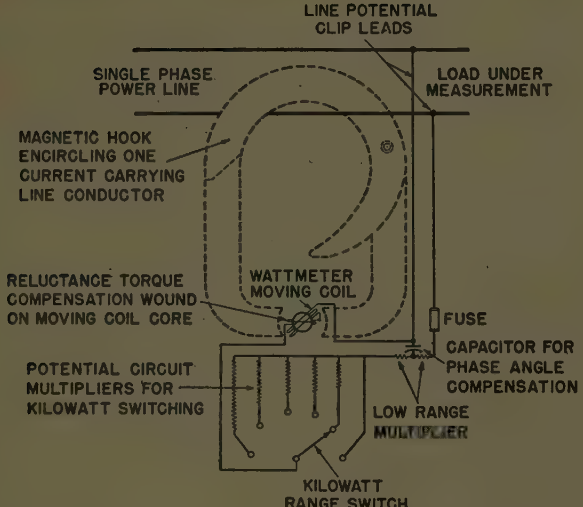

Figure 2. Schematic diagram of hook-on wattmeter. Connections for single-phase power measurement are also shown

Multiple-range accuracy requires that the magnetic circuit deliver useful flux as a linear function of current and without a substantial shift in phase angle over a wide current range. This is accomplished as follows:

1. The concept of a central main core of magnetic material, plus a leakage sleeve, was adopted. The cross section of the leakage sleeve is varied, as far as manufacture will permit, to be proportional to the leakage flux. This proportion contributes to the low weight ($3^1/_2$ pounds) of the instrument.
2. Air gaps are interposed to provide a reluctance sufficiently high to dominate the magnetic circuit and to provide insulation between current and potential circuits.
3. The magnetic hook must be in such mechanical form that it can be opened and closed. The effect of the resultant discontinuity in the magnetic circuit is minimized by the use of a long dove-tail joint.
4. There is an appreciable lagging phase displacement of the mutual flux with respect to the current. Compensation is effected by lagging the potential circuit current correspondingly by a shunt capacitor.

The scale distribution for the six ranges is substantially linear. It is influenced by the linearity of the hook magnetization curve and by the moving-coil reluctance torque. This reluctance torque is due to the circumstance that the total flux linking the moving coil, as a result of moving-coil magnetomotive force only, is a function of coil position. The effect is usually negligible in a construction of this kind, but in the hook-on wattmeter, with its necessarily wide range of moving-coil magnetomotive force, the error is appreciable. Compensation is, therefore, necessary and consists of a series magnetizing winding centrally located on the core (Figure 2). The winding provides a counter torque of approximately the same relationship as the reluctance torque.

This development has resulted in the extension of the hook-on method of measurement to include single-phase and polyphase power. It has been accomplished by development of a lightweight portable single-phase hook-on wattmeter, having wide measurement range. The initial accuracy is three to five per cent of full scale, and quick indication is obtained by magnetic damping and a low-moving system-free period.

Digest of paper 50-111, "Power Measurement by the Hook-On Method," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE North Eastern District Meeting, Providence, R.I., April 26–28, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Reactors With a Low-Impedance Control Source

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THIS ANALYSIS of series-connected saturable reactors is based on core materials whose magnetic properties can be approximated by a rectangular flux-density–field-intensity curve. The circuit is shown in Figure 1. Switch S is in the position as shown, and therefore the feedback windings $Z1$ and $Z2$ are de-energized.

During steady-state operation, the average load current I_L is proportional to the average control current I_C

$$I_L N_L = I_C N_C \tag{1}$$

where N_L denotes the number of turns of the load winding ($X1$, $X2$) and N_C the number of turns of the control winding ($Y1$, $Y2$). There are obvious limitations to equation 1; the load current reaches an upper limit which is dictated by the load resistance and has a lower limit which is controlled by the maximum impedance of the saturable reactors A and B. The region in which equation 1 holds is called the proportional region.

If the control current is held constant but the line voltage is increased, starting from zero, the load current first increases linearly with the line voltage, then remains nearly constant with increasing line voltage, and finally the load current will again increase with increasing line voltage.

If the frequency of the line voltage is increased starting from zero, the maximum load current at zero frequency is reduced by amounts proportional to the frequency; then upon reaching a certain frequency, the load current will remain essentially constant for increasing frequency.

Increasing the load resistance will hardly affect the load current up to a certain value of load resistance. From there on the load current will be inversely proportional to the load resistance.

If the saturable reactor operates in the proportional region and the control voltage E_C is suddenly changed, the load current becomes an exponential function of time, with the time constant

$$T = \frac{1}{4}\frac{R_L}{R_C'} \text{ cycles} \tag{2}$$

R_L is the resistance of the load circuit, and R_C' is the resistance of the control circuit referred to the load side by the square of the turns ratio. The time constant is the same for increasing or decreasing control voltages. It follows from equation 2 that the same saturable reactor operating at higher frequencies will exhibit greater speed of response.

If the position of switch S is changed to connect 7 with 8, the rectified load current will flow through the feedback windings ($Z1$, $Z2$) and aid the magnetomotive force produced by the control current. This type of feedback is called positive and the same load current is obtained with a smaller control current.

Digest of paper 50-123, "Series-Connected Saturable Reactor With Control Source of Comparatively Low Impedance," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Great Lakes District Meeting, Jackson, Mich., May 11–12, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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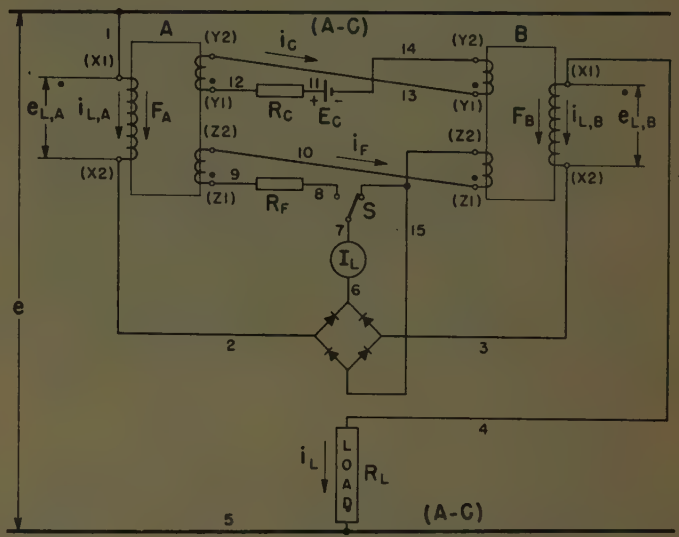

Figure 1. Elementary circuit diagram of the magnetic amplifier showing the feedback windings de-energized

The power gain of a saturable reactor is the ratio of power in the load resistance divided by the power consumed in the control circuit. As positive feedback permits a reduction in control current, the power gain is increased by using positive feedback.

Let the feedback multiplier

$$m_1 = \frac{N_L}{N_L - N_F} \tag{3}$$

where N_F is the number of turns of the feedback winding. The power gain with feedback is approximately m_1^2 times the power gain without feedback.

As a result of positive feedback the speed of response of the saturable reactor decreases. The time constants for increasing and decreasing control voltages are no longer identical. For increasing control voltages, the time constant increases linearly with the feedback multiplier m_1.

By placing a forcing resistor in series with the control circuit, the speed of response can be increased with an attendant proportional decrease of power gain. By increasing the total resistance of the control circuit to m_1 times its previous value, the increase of time constant due to feedback can be eliminated and the power gain is reduced from m_1^2 to m_1. Hence, for increasing control voltages, the saturable reactor with feedback can be made with the same speed of response as the one without feedback and yet have a power gain of m_1 times the power gain of the saturable reactor without feedback.

Industrial Television and the Vidicon

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FELLOW AIEE

The many diverse applications of television outside the field of entertainment are unfamiliar to the average person. This article describes some of these present applications and tells how the vidicon pickup tube, because of its compactness and high sensitivity, makes them possible.

TO THE AVERAGE person television means but one thing—the home receiver to which he and his family may repair for an evening's entertainment or instruction. And, indeed, the growth of the industry which serves this function has been so phenomenal that it may seem unreasonable to ask more of television than the dissemination of cultural values and relaxation through the medium of broadcasting.

Actually, this is only one of the uses of television; others may, eventually, appear even more important. To appreciate its full range, we should recall that television is, in essence, an extension of human sight. As an instance of this, broadcast television extends the sight of the television audience to include the studio presentation, film showing, or other event which has been selected by the broadcaster for its wide appeal. Evidently, this is only a very restricted example of the extension of vision. We are here concerned with the vast number of applications other than broadcasting which, for convenience, are grouped together in the term "industrial television."

More specifically, what are some of these applications? They are to be found wherever the most favorable point of observation of a process or event is dangerous, inaccessible, or uncomfortable for a human being. Heat and fumes generated in chemical processes which may preclude the presence of a human observer have little effect on the operation of a television camera. The same applies to harmful radiations from radioactive materials, which are coming to play an increasing role in research and industry. In the famous Bikini tests television cameras were set up at points at which the presence of human observers would have been unthinkable. Also in standard industrial operations, such as coal mining, industrial television may serve as a valuable complement in mechanization, permitting remote control of the digging machines and increased economy in the following of narrow seams. In the automotive industry, performance tests are facilitated by mounting the television camera at suitable points on the chassis, indicating the reaction of car components from favorable, but normally inaccessible, points of vantage. Finally, the employment of industrial television links for the surveillance of boiler gauges is a specific illustration of their use for the checking of numerous semiautomatic units from a single central station.

The services which industrial television equipment can render in education are comparable to those in industry. Here the pattern resembles, in general, that in broadcast television in so far as the television link serves to increase the audience which can, simultaneously, watch a particular event. However, both the character of the audience and the nature of the event are more highly specialized. Thus, the showing of surgical operations to medical students and visiting physicians has proved particularly valuable; the television camera suspended directly above the subject yields a much more detailed and intimate view of the operation than can be attained even from the best seats of an operating theater. Again, in the biological and related sciences the combination of a television camera with a microscope makes it possible for a large group of students to watch simultaneously the events taking place on a microslide, whether following their natural course or disturbed by micromanipulation. Figure 1 shows a television camera mounted for this purpose on a microscope. In fact, whereever a demonstration is on too small a scale to be successfully observed from the back seats of an auditorium, industrial television becomes a valuable educational accessory.

Figure 1. Television camera mounted with a microscope, which makes it possible for a large group of students to watch simultaneously the events taking place on a microslide

One of the features which makes the use of the industrial television camera attractive in connection with surgical operations is that it is an "aseptic observer," which introduces a minimum of disturbance. The same property might well be employed to give visitors visual access to astronomical observatories and their carefully adjusted giant

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telescopes, without any danger of upsetting their thermal or mechanical balance.

Industrial television also has, of course, its purely commercial applications. Thus, it gives large department stores the opportunity of presenting to customers, at a number of strategic points in the store, fashion shows and exhibitions of goods whose sale they wish to stress. Whereas advertising by broadcast television may implant an interest in the advertised merchandise in the public at large, industrial television may be employed to direct the customer when he is already minded to make a purchase.

Before proceeding to a discussion of actual industrial television equipment, it may be worth while to point out a feature which should prove particularly attractive to the television development engineer. This is the fact that industrial television provides a field for testing the effectiveness of novel techniques in picture signal generation, transmission, and reception, unhampered by the necessity of adhering to pre-established standards. Since every television link is a closed system, its operation may be planned exclusively on the basis of effectiveness and economy. At the same time, the experience which has been gained in industrial television may react favorably on the development of broadcast television.

It may be taken for granted that the best possible design for any one application of industrial television will not be quite the same as that for any other. However, the requirements of the majority of applications are sufficiently similar to permit the development of standard equipment which combines great versatility with moderate cost. Figure 2 shows an industrial television link constructed on this basis.* It consists of a camera, a receiver-monitor, and some 500 feet of connecting cable. Some of its distinctive features are

1. High sensitivity and compactness of the camera.
2. Remote control of the camera from the receiver-monitor.
3. The employment of broadcast television standards to the extent of making possible the insertion of standard receivers at the viewing terminal.

Figure 2. Industrial television system

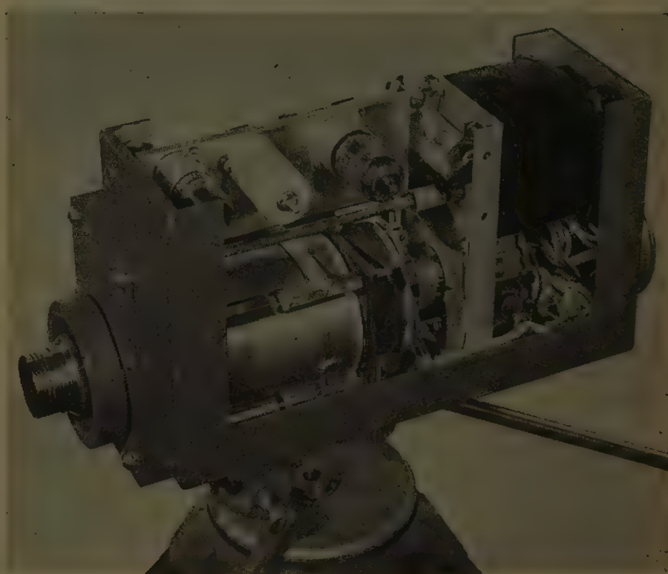

Figure 3. Camera, with cover removed

The camera (Figure 3) weighs only about eight pounds. It is a flat box, 10 by 5 by $3^1/_4$ inches in dimension, with the lens and the cable connector at the two ends. The lens is a standard objective for 16-millimeter motion picture film in a focusing mount which is rotated by a monitor-controlled motor at the back of the camera case. Apart from this motor and the video preamplifier, in the upper half of the case, the camera contains only the pickup tube and its magnetic focusing coil, gun alignment coil, and deflecting yoke.

The character of the pickup tube is primarily responsible for the compactness, but high sensitivity, of the camera. It is a vidicon[1] which resembles the magnetic orthicon in geometry and in the method of focusing and deflection (Figure 4), but differs from it in the nature of the photosensitive target. The latter is, in the vidicon, a photoconductive layer with a sensitivity of some hundreds of microamperes per lumen. The transparent signal plate, on which the photoconductive layer is deposited, is biased 10 to 30 volts positive with respect to the gun cathode. In darkness the layer acts as an almost perfect insulator, so that its surface assumes a potential substantially equal to the cathode potential under the beam and retains this potential up to the next scan. At an illuminated point, on the other hand, positive charge proportional to the illumination is transferred from the signal plate to the surface throughout the period between scannings. This charge is released by the beam in its sweep, giving rise to the picture signal. From the operation described it is evident that, at high light levels, the target surface can rise at most by the bias voltage, in other words, 10 to 30 volts. Thus very high light levels do not lead to instability as in the orthicon, but simply to the blotting out of contrast.

Figure 5 indicates the small dimensions of the vidicon as compared with a standard image orthicon. The outside

* "Industrial Television," R. C. Webb, J. M. Morgan. Presented at Annual Meeting Institute of Radio Engineers, New York, N. Y., March 7, 1950.

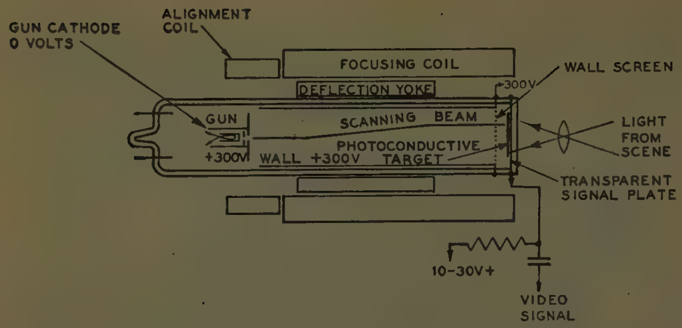

Figure 4. Schematic diagram of vidicon

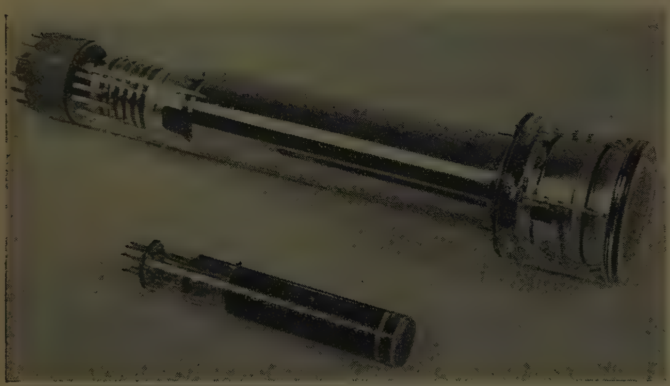

Figure 5. Vidicon and image orthicon

tube diameter is one inch and the target area normally utilized corresponds to one frame of 16-millimeter film. Nevertheless, picture resolution adequate for the full utilization of a standard television channel can be achieved with such tubes.

The receiver-monitor or master control unit (Figure 6), which weighs about 58 pounds and is 24 by 15 by $8^1/_2$ inches in dimension, contains, in addition to the kinescope and its associated circuits, controls and power supplies for the camera. It contains altogether about 44 tubes and consumes approximately 350 watts of 115-volt 60-cycle-per-second power. A fan at the rear, behind the power supplies, prevents any overheating of the compact equipment. The video-amplifier strip is visible at the bottom of the case, the kinescope at the upper right.

The control knobs are placed directly below the kinescope face on the front of the unit (Figure 2). They determine the beam current, blanking adjustment, optical focus, and magnetic focus of the pickup tube as well as the signal level and brightness at the kinescope. A jack at the rear of the cabinet permits connection of the video-amplifier output to a standard receiver unit by means of 75-ohm cable.

Although the standards of the system are essentially those of broadcast television, several of the circuits employed are unconventional. This applies, in particular, to the generation of the deflection and synchronization signals. The deviations from standard television practice are dictated in part by the necessity of transmitting the deflection signals over some 500 feet of 52-ohm cable from the control unit to the camera; in part they are a consequence of the simplification in the vertical synchronizing signal which is permitted by the freedom from interference signals present in a closed system.

The central element in the generation of the deflection saw-tooth waves and synchronizing signals is an oscillator[2] which resembles the multivibrator. This oscillator provides, at different points of the circuit, both a saw-tooth voltage and a sharp pulse voltage. A master oscillator of this type, with a frequency of 31.5 kc per second—twice line frequency—is followed by a sequence of oscillators with submultiple frequencies, the frequency-reduction factors being 7, 5, 5, and 3. Each oscillator is locked in step with the preceding one with the aid of the latter's pulse output. The last oscillator of the chain has a frequency of 60 cycles per second and supplies the vertical blanking pulse. Comparison of the output of this oscillator with the power-line frequency generates an automatic frequency-control signal which locks the master oscillator in step with the power line. The front edge of the vertical blanking pulse, in conjunction with a pulse delay tube, furthermore controls a second 60-cycle-per-second oscillator, from which a simplified vertical synchronizing signal is derived. Its duration is less than half a line period, so that, with interlaced scanning, it can be inserted alternately just ahead and just behind the nearest horizontal synchronizing pulse.

The problem of transmitting the deflection signals over the cable is solved in the following manner: The inductance L, represented by the deflection coil, is shunted by a capacitance C such that $\sqrt{L/C} = R$, the impedance of the cable. In addition, the resistive component of each branch of the resulting parallel resonant circuit is made just equal to R. Then the input impedance of this circuit, which is critically damped, becomes simply R at all frequencies so that it provides a reflection-free termination for the cable. To determine the proper wave form at the input of the cable, it is then only necessary to add the voltage waves generated by the desired saw-tooth currents across the coil inductance and the resistance R in series with it; these are a pulse wave and a sawtooth, respectively. Fortunately, both the sawtooth and the pulse components of the resultant wave are available directly at the appropriate oscillator. They only have to be added in the proper proportion and be amplified subsequently by a small class A amplifier. The final stage of this amplification is in the camera itself.

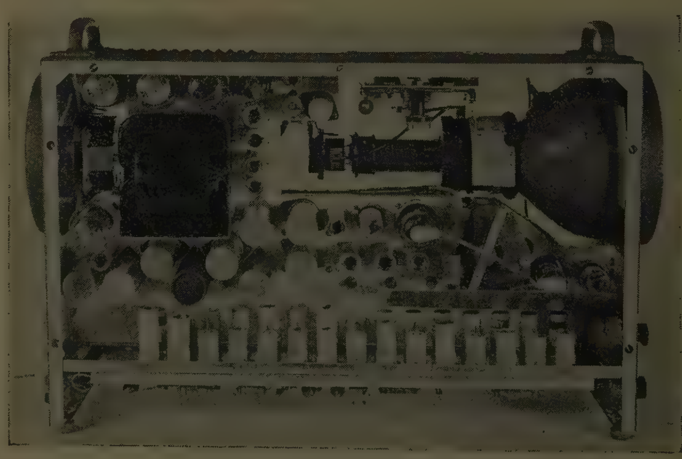

Figure 6. Master control unit, side panel removed

The performance of the simple television link just described has been found entirely satisfactory. There are, however, a number of steps which may be taken—and, in part, have been taken, at least on an experimental basis—to extend the scope of industrial television equipment.

One of the most obvious of these steps is that of adding color. Although for a large number of applications this is of secondary interest, there are others where it can contribute very greatly to the informativeness and value of the pictures transmitted. Among the various applications of industrial television which were listed before, the presentation of surgical operations and the exhibition of goods and fashions in department stores fall into this category.

A straightforward method of achieving a satisfactory industrial color camera consists in imaging the scene through a dichroic beam-splitting system on the photoconductive surfaces of three vidicons with different spectral characteristics. The outputs of these three vidicons control the pictures appearing on the faces of the three kinescopes in a color receiver, which yields a natural-color picture by optical superposition. Once again the compactness of the vidicon is here a decided advantage. This is, of course, but one way in which color transmission can be achieved in industrial television.

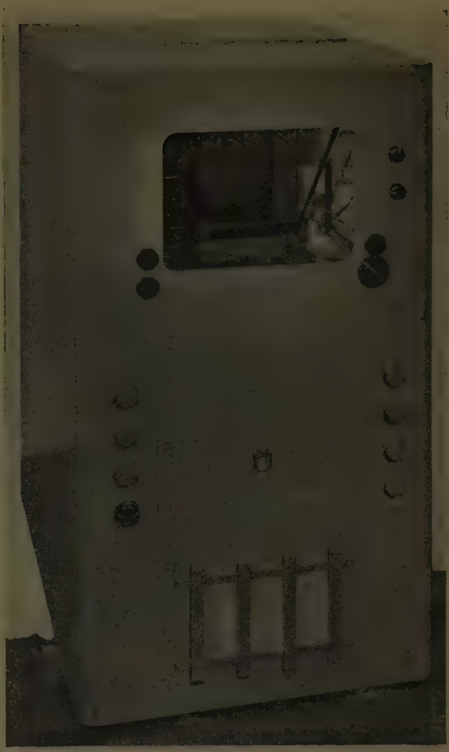

Figure 8. Console receiver for stereo images. In this receiver the images from two kinescopes are superposed by a semireflecting mirror and are viewed through polaroid spectacles, so that each eye sees one of the two images

Another extension of the industrial television system which may be of considerable value in specialized applications is the addition of a third dimension to the pictures viewed. For this purpose two cameras mounted side by side are employed, viewing the object from slightly different angles. The signals are transmitted (over two channels, or by time multiplexing, over a single channel) to two separate kinescopes. If these kinescopes are small in dimension, they may be viewed directly through a lens stereoscope. Otherwise the two images would have to be roughly superposed optically and be observed through polaroid viewers matching complementary polaroid filters in front of the two kinescopes. The second arrangement permits the viewing of the 3-dimensional pictures by larger audiences. It may be noted that, since deflection and synchronizing circuits would be common to the two channels, such a stereo television system does not require complete duplication of a single television link.

Figure 7. Stereo television camera and control units

Figure 7 shows an industrial stereo television system of the type described. The pair of cameras are built into a single unit; the objectives, separated by the normal eye distance, are focused together by a single motor.

Two control units are provided. One of them contains the synchronizing signal generator and a 7-inch monitoring kinescope connected to one of the two video channels. The second, or stereo, monitor contains two small kinescopes with $1^1/_4$-inch screens which are observed through a lens stereoscope. This unit is provided with a pair of jacks from which the video signals for the two kinescopes of a large console receiver (Figure 8) may be obtained. In this receiver the images from the two kinescopes, plane polarized in mutually perpendicular directions by polaroid film, are superposed by a semireflecting mirror and are viewed through polaroid spectacles, so that each eye sees one of the two images. With such an arrangement larger groups can view the 3-dimensional image simultaneously.

Another obvious modification would incorporate a directional ultrahigh-frequency transmitter with the camera so that the cable, at the cost of increasing complexity of the control problem, could be omitted. The stress to be placed on such further developments would depend on a balance between probable utility and probable cost. For the more complex systems of industrial television this balance may be favorable for only a relatively restricted range of applications. This is not true, however, of the simple television link which was described first. In it we have a tool of wide utility which should fill real needs in industry, research, education, and commerce. Such equipment represents a material step forward in the direction of fulfilling the basic function of television—extending human sight.

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Bus Transfer Tests on Station Auxiliary System

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TWO METHODS are used to transfer powerhouse auxiliary busses supplying station auxiliary motors from one source to another; namely, "closed transition" and "open transition." For maximum safety with closed transition the feeder circuit breakers should be capable of interrupting a feeder fault when the two sources are tied together. For open transition the feeder circuit breakers have interrupting capacity to handle the short-circuit kilovolt-amperes from only one source at a time. There is an optimum time interval at which reclosure should be made on open transition to give the least disturbance and provide maximum safety to the station equipment. To determine this time interval, transfer tests were made on the auxiliary power system of the Phillips Power Plant, Duquesne Light Company, Pittsburgh, Pa.

The auxiliary motors in this plant are supplied from two bus sections with one bus supplied normally from the 7,500-kva auxiliary generator (which is on the same shaft with the 75,000-kva main generator), and the other bus from a 7,500-kva station service transformer. Both busses may be supplied from either source. During the tests one bus having a load of about 2,500 kw was transferred from the generator to the transformer and back to the generator several times. Oscillographic records were obtained of power, current, and voltage before, during, and after the transfers for open time intervals from about 11 cycles, as shown in Figure 1, to 150 cycles. Records were taken of the total load and on the largest motors.

The motors consisted of one 1,250-horsepower for a boiler feed pump, two 200-horsepower force-draft fans, two 400-horsepower induced-draft fans, two 250-horsepower pulverizer mills, four 75-horsepower pulverizer exhausters, one 500-horsepower circulating water pump, and one 125-horsepower hot-well pump.

When the source was disconnected, the residual voltage on the bus to which the motors were connected decreased in practically a straight line from 2,300 volts to almost zero volts in 60 cycles. During this period the 1,250-horsepower boiler feed-pump motor supplied electric power to the smaller motors.

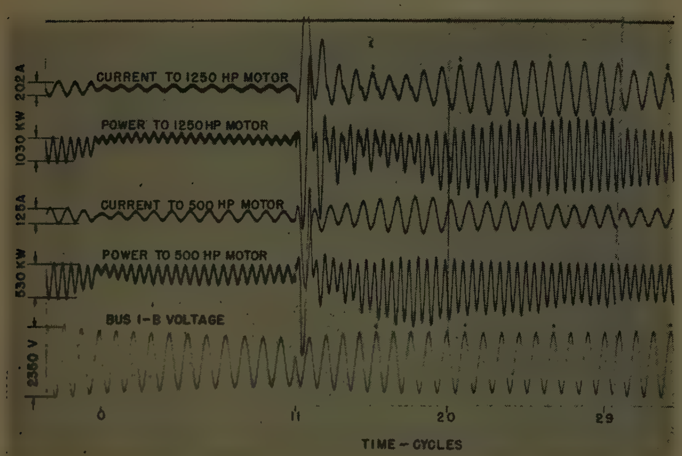

Figure 1. Oscillographic record for transfer interval of 11 cycles for boiler feed pump motor and circulating water pump motor

For transfer time intervals less than 50 cycles because of the residual voltage on the motors, the inrush currents upon re-energizing can be in excess of the current for which the motors are braced. This happens when the phase position of the residual voltage on the motors is at or near 180 degrees out of phase with the new power source voltage. To prevent excessive inrush currents, the open transition time interval for this system should be about 50 cycles. The first half cycle of inrush current to the motors was the largest and is the value of current which must be considered for mechanical strength of the motors. After this first half cycle of high current, in most cases the current decreased sharply and then gradually increased for several cycles to a value corresponding to normal current for motor acceleration from the speed at which it happened to be at that instant. For a 50-cycle time interval, all of the motors were back to normal in about 100 cycles after being re-energized. Since the boiler feed-pump motor was the largest motor and had a high inertia constant, it was the last motor to come back to normal.

When the group of motors was re-energized, the greatest drop in voltage occurred for the fastest transfers. The generator voltage dropped to about 65 per cent of normal following an open time interval of 11 cycles, and recovered to normal in about 50 cycles. For a time interval of 75 cycles, the generator voltage dropped to about 75 per cent, but required an additional recovery time of about 130 cycles.

Tests were satisfactory for all time intervals up to 150 cycles except that the circulating pump was lost on one test. One time interval developed to be about 300 cycles, and a number of the auxiliary motors were shut down by protective relays. Without question, 300 cycles is too long an interval, and, in fact, 150 cycles is also too long. The preferred time interval should be when the residual voltage approaches zero, which for this system is about 50 cycles.

The transfer of auxiliary bus sections by open transition can be safely accomplished. For any auxiliary system the preferred open time interval is determined by the time required for the residual voltage to decay to approximately zero. The actual time should correspond to no less than that which gives an inrush current to the motors equal to or less than the fully offset current each motor takes when started across the line from an infinite terminal source.

Digest of paper 50-59, "Bus Transfer Tests on 2,300-Volt Station Auxiliary System," recommended by the AIEE Committee on Power Generation and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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High-Voltage Oil Circuit Breakers

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The maximum interrupting capacity of steel-tank oil circuit breakers is increasing rapidly. Five years ago maximum values of 5,000,000 kva were being predicted, but today circuit breakers are being built which will interrupt 10,000,000 kva. The time of reclosing these high-capacity circuit breakers is decreasing rapidly, and has been demonstrated satisfactorily with intervals as short as nine cycles.

ONLY a few years ago, 3,500,000 kva was the maximum standard rated interrupting capacity for high-voltage circuit breakers, and the interrupting-time ratings were mostly five and eight cycles. This article describes recent developments in interrupting devices that have made available standard circuit breakers for 5,000,000-kva interrupting capacity and 3-cycle interrupting time for 138-, 161-, and 230-kv voltage classes. Particular attention is directed to the circuit breakers recently shipped to the 230-kv switchyard at Grand Coulee Dam which carry a 10,000,000-kva interrupting capacity rating on a 20-cycle reclosing duty cycle.

In 1945 it was predicted[1] that the growing needs of the electrical industry would soon require installation of high-voltage circuit breakers having interrupting capacity in excess of the then maximum available rating of 3,500,000 kva.

Now circuit breakers are being built for not only 5,000,000 kva but as high as 10,000,000 kva. Recognition of these growing demands for higher interrupting capacity is indicated by the "Schedule of Preferred Ratings for Power Circuit Breakers,"[2] approved January 24, 1949, which list 5,000,000-kva ratings for 3-cycle oil circuit breakers in the 138-, 161-, and 230-kv voltage classes. Further evidence that this demand is not confined to one or two specific locations can be gained by considering the various places where high-power circuit breakers having 5,000,000-kva interrupting capacity or higher are actually being installed: 230-kv 10,000,000-kva circuit breakers for both Grand Coulee Dam and Hoover Dam; 230-kv 5,000,000-kva at 25-cycle frequency for the Hydro-Electric Commission of Ontario; 230-kv 5,000,000-kva at 50-cycle frequency for Electricite de France; 161-kv 5,000,000-kva for the Aluminum Company of America in Tennessee; and 138-kv 5,000,000-kva for the Ohio Power Company and Consolidated Edison Company of New York. These installations comprise 76 complete 3-pole circuit breakers from one manufacturer and its Canadian affiliate alone, representing an investment of between four and five million dollars, with an appreciable number of additional high-power circuit breakers being built by other manufacturers for these and other power systems such as the Pacific Gas and Electric Company and the Bonneville Power Administration. The specifications for many of these circuit breakers provide that they shall be capable of performing on rapid reclosing duty.

The steel-tank circuit breaker (Figure 1) has undergone continuous development during the past 30 years, taking in its stride a reduction in interrupting time from 25 cycles to 3 cycles and an increase in interrupting capacity from 1,000,000 to 10,000,000 kva with a simultaneous reduction in physical dimensions. The availability of high-power laboratories has accelerated the design of more and more effective types of arc-extinguishing devices. Field tests, particularly those which provide short-circuit power in excess of that available in the laboratories, have been particularly helpful in verifying extensions of circuit-breaker interrupting capacity into the higher ratings beyond 3,500,000 kva.

The design features and laboratory and field performance of extra-heavy-interrupting-capacity circuit breakers being developed for 230-kv 3-cycle performance were described in 1948.[3-5] It was concluded, at that time, that circuit breakers up to 10,000,000 kva for use at Grand Coulee Dam were entirely feasible. In a paper by Leeds and Cushing,[3] the elements of a steel-tank circuit breaker for heavy-duty interruption at high speed were outlined. Because of the relatively small amount of gas associated with the interruption of high-power arcs using modern interrupting devices, the tank diameter and clearances

Figure 1. 230-kv 3-cycle oil circuit breaker at Columbia Substation on the Bonneville Power Administration system

Essentially full text of paper 50-12, "High-Voltage Oil Circuit Breakers for 5,000,000- to 10,000,000-Kva Interrupting Capacity," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 30–February 3, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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between live parts and ground are dictated almost entirely by the requirements of the standard 1-minute insulation test. At the present time, the minimum tank diameters appear to be in the neighborhood of 54 inches for 138 kv, 62 inches for 161 kv, and 78 inches for 230/196 kv. The dimensions of the highest power interrupter assemblies make it necessary, in some cases, to increase these minimum diameters slightly.

Since the more conventional features of a heavy-duty high-speed steel-tank circuit breaker, such as oil-impregnated bushings and pneumatic operating mechanism, were adequately described in earlier papers, this discussion will emphasize primarily the special design improvements, particularly in the interrupter assemblies, which have been developed recently to increase the speed of operation and maximum rupturing capacity on both standard and high-speed reclosing duty.

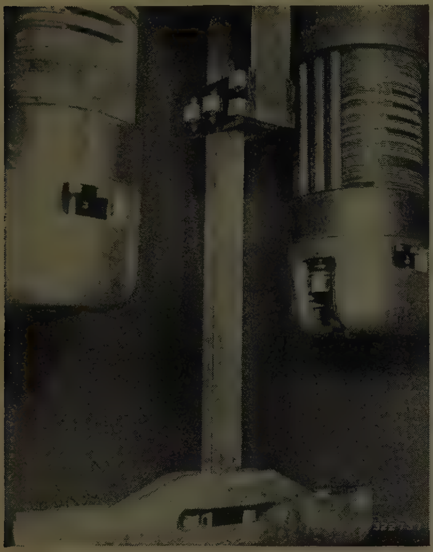

Figure 2. View of the multiflow grid interrupters inside one pole of a 230-kv 3-cycle circuit breaker rated 10,000,000 kva

The view in Figure 2, through the manhole of a 230-kv 10,000,000-kva circuit breaker, shows the location of a pair of heavy-duty multiflow "De-ion" grid-contact assemblies for one circuit-breaker pole. Only one interrupting unit per terminal is required, even for a 3-cycle interrupting time, because of the exceptional effectiveness of the arc-extinguishing elements. The aluminum moving contact bridges across the two contact assemblies when it is raised to the closed position by the insulated lifting rod.

The relative size of four different interrupter assemblies rated 5,000,000 kva at 138, 161, and 230 kv and 10,000,000 kva at 230 kv is illustrated in Figure 3. The functioning of these interrupters is substantially the same for each rating, the primary difference being in the physical dimensions. The compactness of design is indicated by the fact that even the 10,000,000-kva unit shown on the right is only 40 inches tall. Figure 4 shows the 230-kv 10,000,000-kva interrupter in schematic cross section, and illustrates the essential functions of the several assemblies. This grid is of the multiflow type which draws two arcs simultaneously; pressure generated by the upper arc results in a flow of oil down two channels and then horizontally inward at a number of levels to converge on the arc in the lower break. The turbulence created by the intimate contact between the arc and oil is responsible for a high degree of interrupting effectiveness. Venting takes place through windows located front and back at levels intermediate between the inlet channels.

Surrounding the lower moving contact there is a spring-driven annular piston which supplements the oil flow from the pressure-generating gap when interrupting low magnetizing and line-charging currents. By this means, flat 3-cycle interrupting time is obtained for all values of current which the circuit breaker may be called on to interrupt. At higher currents, where the pressure produced is greater than that obtainable from the piston, the piston does not operate until after arc interruption occurs, and then serves to flush residue arc products from the grid. This function is of particular value on high-speed reclosing where it is desirable to clean out the gases remaining from the first interruption before the circuit breaker may be called on to open the circuit a second time within 20 cycles or less. For the interruption of line-charging currents where it is desirable to avoid arc restrikes that develop overvoltage surges, the oil-piston action is purposely delayed so that interruption will be attempted only after the contacts have

Figure 3. Heavy-duty 3-cycle multiflow grids rated 138, 161, and 230 kv at 5,000,000 kva, and 230 kv at 10,000,000 kva

parted sufficiently to be able to support the double voltage that appears one-half cycle later.

An important new feature is the arrangement by which the intermediate contact is spring-biased upwards and is free to move for one-half inch from the closed position. During an opening operation, the intermediate contact moves upwards for this distance together with the tip on the rocker contact. At the same time, the lower contact is accelerated downward so that the interrupting gap is formed at a speed nearly three times that of the moving cross-member during the first quarter inch of circuit-breaker lift-rod travel. This feature makes it possible to eliminate multiplying levers between the lower contact and crossarm, and with only a slight increase in lift-rod speed the desired high-speed interrupting time and no-restrike performance on line-charging currents is obtained. The fact that the formation of the upper pressure-generating gap is delayed by this arrangement makes it possible to interrupt higher power, since excessive pressure is not built up waiting for a sufficient contact separation for arc interruption in the main contact gap.

An oil dashpot arrangement is incorporated into the upper end of the grid operating rod and is designed to delay relative motion between the rod and links attached to the rocker contact. This is made operative during an opening operation only, using a spring-biased check valve. Thus, during normal rapid opening of the contacts, the rocker contact begins to rotate upward as soon as the moving cross-member moves downward, thus affording further savings in interrupting time.

After the lower grid contact is spring-driven to its open position against a stop, further travel of the moving cross-member forms a disconnect gap below the interrupter. This gap serves to remove voltage from the grid assembly while the circuit breaker stands in the open position, and also interrupts the small fraction of an ampere drawn by the voltage-dividing resistors which are provided to make sure that each interrupter handles its proper share of the recovery voltage.

The use of butt-type contacts with silver-tungsten arcing tips is retained because of the inherent high-speed opening obtained in comparison with finger-type contacts. Since the momentary current-carrying capacity of the contacts for these heavy-duty circuit breakers must be as high as 40,000 amperes, tests have been made to determine the amount of spring-loading required to assure the ability to handle this large amount of current without welding or excessive pitting of the contacts. Adequate heat conduction away from the sources of heat generation is provided to pass a 25,000-ampere current-carrying test for the rated 4-second period, and to carry continuously loads as high as 1,200 amperes without excessive temperature rise. An undesirable additional heat source from the helical springs which surround the grid contacts can be avoided by the use of nonmagnetic stainless steel for these items.

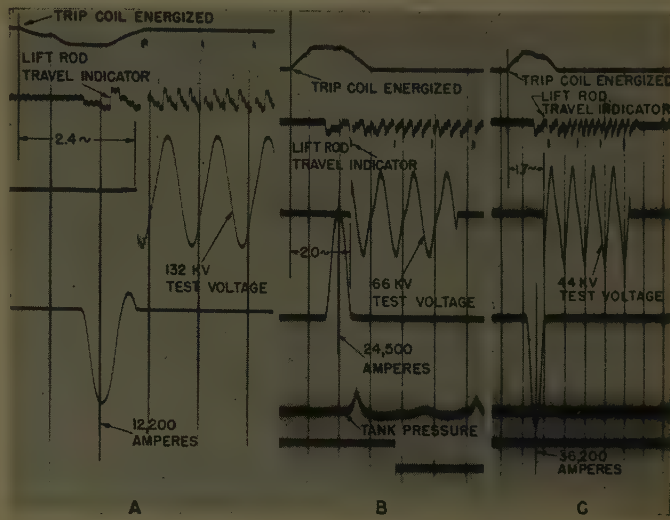

Figure 5. High-power laboratory tests on 230-kv 10,000,000-kva circuit breaker

A—132 kv, 12,200 amperes single pole—equivalent three phase, 230 kv, 4,870 megavolt-amperes

B—66 kv, 24,500 amperes half pole—equivalent three phase, 230 kv, 9,760 megavolt-amperes

C—44 kv, 36,200 amperes half pole—equivalent three phase, 230 kv, 14,500 megavolt-amperes

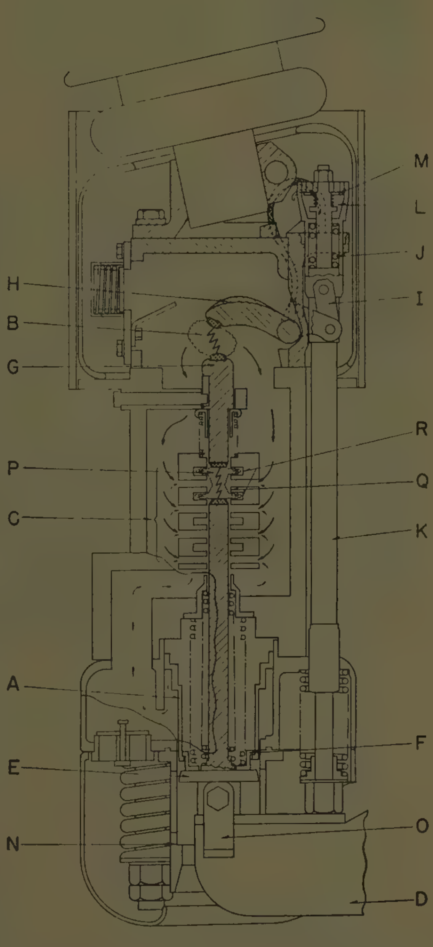

Figure 4. Cross section of 230-kv 10,000,000-kva multiflow grid

Light arrows indicate path of oil flow from piston A, augmenting flow (heavy arrows) from pressure-generating arc B to interrupting section C. When circuit breaker is tripped, cross member D moves down, followed by contact E and collar F which picks up piston after short delay to provide time for adequate contact separation for charging current interruption without restriking. Intermediate contact G is biased upward, following rocker contact H for a short distance. Contact H is rotated to open position through links I and contact-loading spring J by means of operating rod K. Oil dashpot L opposes extension of spring J, speeding opening of contact H, but closing action is free due to check valve M. Lower contact E is stopped on shoulder N, allowing crossarm D to pull out of fingers O to form an isolating gap after arc extinction. Vents R from interrupting section C are separated from oil channels by orifice plates Q

The interrupting time of a circuit breaker includes three steps: the time from energizing the trip coil until the circuit breaker mechanism is unlatched; the mechanical time required to separate the circuit-breaker contacts; and the arcing time. While the first two steps take a fairly constant time interval, the arcing period is affected by the random occurrence of current zero with respect to the parting of the contacts so that a variation of at least plus or minus one-half cycle in the arcing time, and therefore, in the total interrupting time, is inevitable. A typical timing test on a tripping operation of the 230-kv 10,000,000-kva 3-cycle circuit breaker shows 0.6 cycle to unlatch, 0.6 cycle to part contacts after unlatching, and an arcing time of 0.8 to 1.3 cycles on fault interruptions, giving a total interrupting time of 2.0 to 2.5 cycles.

The closing time from energizing the electrically operated air valve until the contacts touch, requires only about 18 cycles, of which $1^1/_2$ cycles represent the time to get the inlet valve open and high-pressure air on the piston of the pneumatic operating mechanism. A specially designed large-size air inlet valve with a 2-inch diameter port, together with a 2-inch flexible hose connection, is

provided for the 10,000,000-kva circuit breaker to keep the cylinder pressure close to that in the air reservoir during a closing operation.

A normal 20-cycle reclosing operation is obtained by energizing the closing contactor from a 2-pole switch on the operating mechanism which makes up its contacts when the circuit breaker has opened about half way. The air pressure admitted to the main cylinder brings the circuit breaker to rest a little short of the full open position, reverses the movement quickly, and sends the circuit breaker back to the closed position. By advancing the position at which the 2-pole switch initiates the closing function, the reclosing time interval, measured from energizing the trip coil to the instant when the contacts touch on reclosure, may be reduced to as short as 12 cycles. By a reconnection of the control circuit so that the closing valve is energized directly by the 2-pole switch, reclosing times as short as nine cycles have been obtained on the 230-kv 3-pole circuit breaker operated by a single pneumatic mechanism. Insulator flashover deionization has been found to take from 10 to 16 cycles after fault interruption in the 3,500,000- to 10,000,000-kva range at 230 kv,[6] so that practical reclosing time intervals for 3-cycle circuit breakers at this voltage appear to be limited to not less than 15 cycles. However, it is evident that faster reclosing can be made available if the need for it should arise.

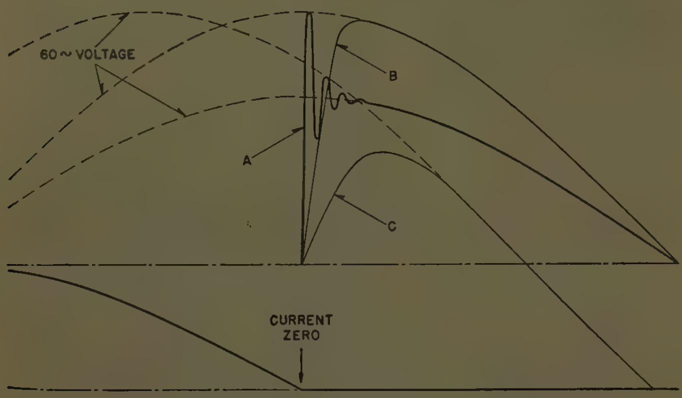

Figure 6. Comparison of high-power laboratory and field recovery-voltage transients across single interrupter

A—44-kv 10,000-cycle undamped laboratory circuit with symmetrical short-circuit current of 20,000 amperes

B—66-kv damped transient on Grand Coulee circuit with symmetrical short-circuit current of 10,000 amperes

C—66-kv damped transient on Grand Coulee circuit with asymmetrical short-circuit current of 18,200 amperes

The limitations of high-power laboratory test power usually make it necessary to do most of the testing on a single-pole unit instead of making full 3-phase fault interrupting tests. The "Test Code for Power Circuit Breakers,"[7] paragraph 9–1.3.4, states, "the voltage to be used in making single-pole tests is determined by the manufacturer, because he is responsible for the adequacy of the voltage used to demonstrate the ability of a circuit breaker to meet its rating." Even with effectively grounded systems, 3-phase ungrounded faults can occur, for instance, as a result of a steel cable being dragged by an airplane across all three phases of a transmission line, so that the condition of 87 per cent of line voltage across the first pole to clear must be considered as a possibility.

Another abnormal voltage condition may occur during transient instability when two parts of a system swing out of synchronism so that a tie circuit breaker could be called upon to interrupt practically double normal line-to-ground voltage across terminals, equivalent to approximately 115 per cent of line-to-line voltage across a single pole. For these reasons, it is considered desirable to demonstrate adequate voltage-interrupting ability of a high-voltage circuit breaker by including single-phase interrupting tests opening reasonable amounts of power, up to perhaps 25 per cent of the current-interrupting capacity, with voltages as high as twice normal line-to-ground potential. As indicated by the test data in Table I, all of the 5,000,000-kva circuit breakers have been subjected to such factor-of-safety tests in order to be sure that the voltage-interrupting ability of these circuit breakers is adequate for any reasonable abnormal voltage condition to which it may be subjected in service.

Heavier power interrupting tests have also been made at normal line-to-ground voltage to the maximum power of the laboratory. By taking advantage of the maximum asymmetry in the short-circuit current, obtained by synchronous control of the laboratory closing switch, and by pretripping the test circuit breaker so that the contacts separate during the first cycle of fault current, single-phase power can be interrupted equal to slightly more than 1,500,000 kva, equivalent to a 3-phase fault approximating 4,800,000 kva. The oscillogram of Figure 5*A* shows such a test in which 12,200 amperes are interrupted at 132,000 volts to ground in a time of 2.4 cycles. Still higher powers up to twice this value of 9,600,000 kva are made available by shunting out one of the interrupting units in the test pole and applying the full power of the laboratory at approximately one-half normal line-to-ground voltage across the half-pole unit. Such a test is shown in Figure 5*B* opening 24,500 amperes at 66,000 volts in 2.0 cycles. In verifying the capabilities of the 230-kv 10,000,000-kva circuit breaker for Grand Coulee Dam, even the test program just outlined fell a little bit short of the necessary power to demonstrate the rupturing capacity with a reasonable factor of safety.

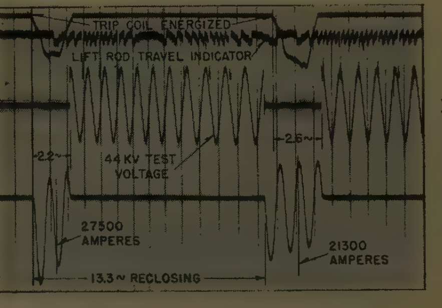

Figure 7. Oscillogram of 13.3-cycle reclosing duty cycle test on 230-kv 10,000,000-kva circuit breaker opening 27,500 amperes at 44 kv across a half-pole unit equivalent to a 3-phase fault of 11,000,000 kva at 230 kv

Accordingly, further tests were made on a half-pole unit

with the 44-kv transformer connection instead of 66 kv. By this means the oscillogram of Figure 5C was obtained showing a short-circuit current of 36,200 amperes, which at 230 kv, three phase would be a fault of 14,400,000 kva. Since the 60-cycle recovery voltage was now only two-thirds of the appropriate value for a single interrupting unit, it might be considered that this test was not valid in terms of both voltage and current which were involved in the interruption.

However, the very high rate of recovery voltage in the laboratory and amount of overswing at the first transient voltage peak, compared to the damped recovery voltage of a high-power fault circuit in the field, makes this test one of equal or even greater severity. In Figure 6 is replotted to a suitable time scale the recovery-voltage transient from a symmetrical current interruption at 44 kv in the laboratory compared with the recovery transients from high-power 230-kv field tests at Grand Coulee Dam having both asymmetrical and symmetrical fault current. Not only is the rate of rise of recovery voltage highest on the laboratory test, but the amplitude of the first voltage peak is equal to or greater than both of the field test-voltage transients. On this basis the 13.3-cycle reclosing test of Figure 7, opening a current ten per cent above the 25,000-ampere rating of the 10,000,000-kva circuit breaker, may be considered as imposing recovery voltage conditions on the interrupting unit at least as severe as would be encountered on a 230-kv system without pretripping and with only moderate current asymmetry.

Considering the wide range of voltage and current to which a circuit breaker is subjected during verification, it is remarkable how little variation there is in the interrupting time. The effectiveness of the multiflow principle of interruption, supplemented by a spring-driven oil piston to assist the interruption of low current, is indicated by the fact that currents from 0 to 100 per cent of the current-interrupting capacity are all interrupted within the 3-cycle interrupting time. Interruption, even at voltages approximating twice normal line-to-ground voltage, only occasionally exceeds the rated time of three cycles. When considering piston-driven oil flow for the interruption of line-charging current with minimum arc restriking in comparison with self-generated oil flow alone or with parallel voltage-damping resistors, the ability to meet a flat 3-cycle interrupting time characteristic over the entire current range using the oil piston is a considerable advantage in its favor, as well as the interrupter-flushing action obtained during each operation.

Figure 8. Appearance of intermediate-contact arcing tips of 230-kv 10,000,000-kva interrupter after nine consecutive interrupting tests at 25,000 to 30,000 amperes, all above the rated current-interrupting capacity

Table I. Factor of Safety, High-Power-Laboratory Interrupting Tests

Circuit Breaker Rating	Test No.	Single-Phase Voltage, Kilovolts	Interrupted Current, RMS Amperes	Interrupting Time, Cycles	Equivalent 3-Phase Kva
138 kv	1	160	160	2.4	77,000
5×10^6 kva	2	160	1,160	2.9	557,000
3 cycles	3	160	3,500	2.8	1,680,000
	4	160	4,570	2.7	2,190,000
	5	160	6,030	2.8	2,900,000
161 kv	1	198	160	2.8	95,000
5×10^6 kva	2	198	1 300	2.3	770,000
3 cycles	3	198	2,150	2.5	1,280,000
	4	198	3,000	2.7	1,780,000
	5	198	4,950	2.7	2,950,000
230 kv	1	264	120	2.2	95,000
5×10^6 kva	2	264	1,000	2.7	790,000
3 cycles	3	264	2,100	2.4	1,660,000
	4	264	3,200	2.4	2,530,000
	5	264	3,750	2.8	2,960,000

The Leeds-Cushing paper[3] presented comparative results of heavy fault interruptions both in the High-Power Laboratory and at Grand Coulee Dam on a 230-kv circuit breaker. These tests demonstrated that voltage conditions in the laboratory test imposed equal or greater severity as compared to the field tests. However, it is extremely valuable to have the opportunity of testing ultrahigh-interrupting-capacity circuit breakers directly on a power system to supplement and confirm results obtained in the laboratory. Further tests at Grand Coulee Dam are planned in the near future to carry single-phase fault interruptions to equivalent 3-phase fault values as high as 12,000,000 kva.

The standard operating duty cycle for power circuit breakers has been based for a number of years upon the close-open–15-second–close-open duty. The Standard, "Alternating-Current Power Circuit Breakers"[8] says: "After a performance at or near its interrupting rating, it is not to be inferred that the circuit breaker can meet its interrupting rating without inspecting and, if necessary, making repairs." The improvement in circuit interruption, particularly in the higher power 3-cycle circuit breakers described in this article, has resulted in circuit-breaker designs which are capable of performing their interrupting rating several times on the standard duty cycle without the necessity of inspection or maintenance. Figure 8 shows the condition of the intermediate contact arcing tips of a 230-kv 10,000,000-kva grid after nine consecutive interrupting tests in the laboratory at 25,000 to 30,000 amperes with 44 kv applied to a single unit. The rating factors given in Table I of National Electrical Manu-

facturers Association Standard *SG6-90*[9] for repeated numbers of unit operations and for reclosing operations have been considered by operating people as unnecessarily drastic when applied to the most modern circuit breaker designs. Some liberalization of these factors is being made in a revision now in progress, but of necessity they must be standardized at values which can be met by a wide variety of circuit breakers. While some reduction in interrupting capacity is indicated by rapid reclosing tests on circuit breakers of the self-generated oil-flow type, the actual loss of interrupting ability on the second operation is not very great on 3-cycle high-power circuit breakers which have been designed with an appreciable factor of safety in arc-rupturing capacity.

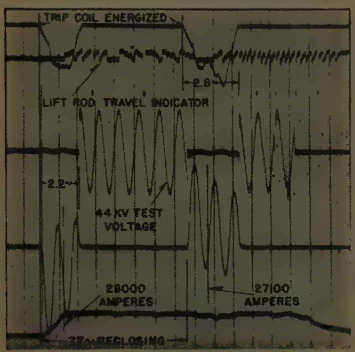

Figure 9. Oscillogram of 7.7-cycle reclosing duty test on 230-kv 10,000,000-kva circuit breaker opening 28,000 amperes at 44 kv across a half-pole unit equivalent to 3-phase fault of 11,200,000 kva at 230 kv

The data submitted in Table II are selected from the large number of interrupting tests made in the high-power laboratory during the development and verification of the 3-cycle circuit breakers rated 5,000,000 kva at 138, 161, and 230 kv, and the 10,000,000 kva circuit breaker for 230 kv. Standard-duty and rapid-reclosing tests are included, with the fault power applied to a single-pole unit or only a half-pole as found necessary to demonstrate adequate interrupting ability. Of particular interest is the extremely fast 7.7-cycle reclosing test at 28,000 amperes, the oscillogram of which is shown in Figure 9. This represents voltage and current conditions applied to a single interrupting unit which is equivalent to a 3-phase fault of 11,200,000 kva at 230 kv.

From both theoretical considerations and the results of actual tests there does not seem to be any serious limitation on the maximum interrupting capacity of steel-tank oil circuit breakers equipped with heavy-duty multiflow "De-ion" grid interrupters. Although 25,000-ampere interrupting capacity and 40,000-ampere momentary rating is close to the limitation of the butt-type contacts with silver-tungsten arcing tips, interrupters using finger-type contacts, with a slight increase in over-all interrupting time, can be made available if, in spite of more conventional practices limiting maximum fault power, still higher rupturing capacities seem justified.

By taking advantage of the inherently higher rate of rise of recovery voltage in undamped laboratory test circuits as compared to the overdamped transients under heavy fault conditions in the field, the test voltage in the laboratory may be lowered by as much as a third, thus expanding the available rupturing capacity by 50 per cent without serious loss in validity of the results.

High-speed reclosing, even at intervals as short as nine cycles, has been demonstrated satisfactorily, indicating that the circuit breaker need not be the limiting factor in establishing the shortest interval which would be practical for reclosing.

Table II. Heavy-Duty High-Power-Laboratory Interrupting Tests

Circuit Breaker Rating	Test	Single-Phase Voltage, Kilovolts	Interrupted Current, RMS Amperes	Interrupting Time, Cycles	Equivalent 3-Phase Kva
138 kv	Full pole—O*	88	9,100	2.4	2,170,000
5×10^6 kva	—O	66	23,200	2.2	5,530,000
3 cycles	Half pole—O	44	28,400	2.9	6,780,000
	20 cycle—OCO†	44	19,500	2.6	4,650,000
			17,850	2.9	4,250,000
161 kv	Full pole—O	88	14,800	2.5	4,120,000
5×10^6 kva	Half pole—O	44	20,600	2.7	5,720,000
3 cycles	20 cycle—OCO	44	17,100	2.7	4,760,000
			14,700	2.9	4,100,000
230 kv	Full pole—O	132	9,400	2.5	3,750,000
5×10^6 kva	Half pole—CO	66	13,600	2.3	5,410,000
3 cycles	20 cycle—OCO	66	13,000	2.4	5,180,000
			12,500	2.8	4,980,000
230 kv	Full pole—O	132	12,200	2.3	4,850,000
10×10^6 kva	20 cycle—OCO	132	9,500	2.3	3,770,000
3 cycles			6,200	2.7	2,460,000
	Half pole—O	66	24,500	2.0	9,700,000
	20 Cycle—OCO	66	13,000	2.4	5,170,000
			12,500	2.8	4,960,000
	Half pole—O	44	36,200	1.7	14,400,000
	13.3 cycle—OCO	44	27,500	2.2	10,900,000
			21,300	2.6	8,450,000
	9.5 cycle—OCO	44	15,900	2.2	6,310,000
			13,000	2.9	5,170,000
	7.7 cycle—OCO	44	28,000	2.2	11,100,000
			27,100	2.8	10,750,000

* O = Open.
† OCO = Open-close-open.

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Force on a Cut Iron Cylinder

In the preceding essay (*EE, June '50, pp 550–1*), Alter Ego's friends, Bill and Charlie, asserted that there is a longitudinal magnetic pull or tension on a cylinder of iron placed in a uniform magnetic field. Jack, however, asserted that there would be a radially outward pull on the sides of the cylinder. However, when Alter Ego offered to demonstrate the existence of these pulls by cutting the cylinder into two halves either crosswise or lengthwise, (Figure 1*A* and Figure 1*B*), all three asserted that in spite

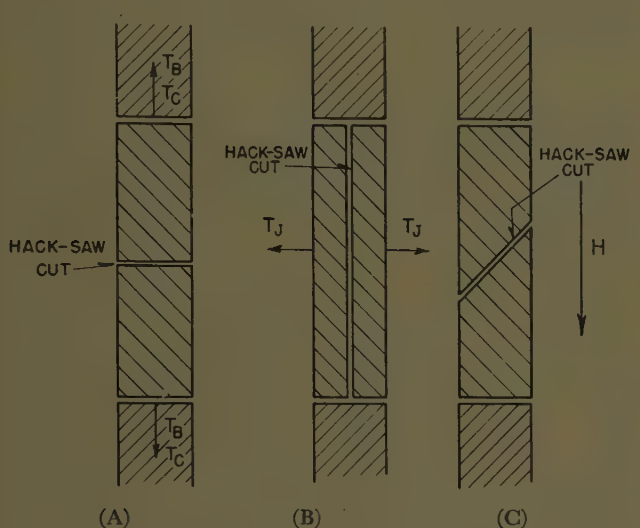

Figure 1. Magnetic pull on halves of iron cylinder

of their respective magnetic pulls, the two halves of the cylinder would not pull apart.

Although they did not say so explicitly, there was an implication that the two halves in each case would be in equilibrium under their respective magnetic forces. This was because Bill, Charlie, and Jack tacitly assumed that they were truly dealing with a 1-dimensional case where **B** and **H** are uniform and constant throughout the whole length of the iron cylinder. In the experiment which Alter Ego proposed, however, this would not have been the case, since the fringing of the magnetic flux would cause **B** to be greater at the middle or equatorial cross section of the cylinder than at the two ends.

However, the magnetic flux density, **B**, could be made more nearly uniform throughout the length of the test cylinder, if the magnet used to set up the field had long circular poles of the same size as the cylinder section, and which were made of the same kind of iron as the cylinder, and which were separated from the cylinder ends by very small air gaps, Figure 1. Then the test cylinder, and the two halves made by Alter Ego's hacksaw cut, would be nearly in equilibrium, Figure 1*A* and Figure 1*B*, as the formulas of Bill, Charlie, and Jack predicted.

Now suppose Alter Ego offered to make a 45-degree cut as in Figure 1*C*. What would Bill, Charlie, and Jack, and you, dear reader, then say as to the resultant two halves pulling apart?

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Symmetrical Components

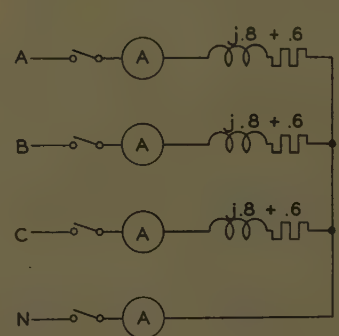
A simple, balanced 3-phase network is shown in Figure 1. Three equal impedances are connected in star. The network's four terminals are connected to a source of positive sequence voltage through four knife switches and four a-c ammeters in series with the knife switches. Three of these are in the line leads and one in the neutral wire of the circuit. The circuit of Figure 1 and any circuit for which the phase sequence impedances are equal ($\mathcal{Z}_0 = \mathcal{Z}_1 = \mathcal{Z}_2$) has the following properties: When any three switches are closed, the associated ammeters read the same value of current; when one of the line switches and the neutral switch are closed, the two associated ammeters also read the same value of current.

Another simple, balanced circuit can be designed to satisfy the requirement that when any two switches are closed, the ammeters in series with these switches will read the same specified value. It is only necessary that the phase sequence impedances satisfy the following expression:

$$\frac{\mathcal{Z}_0+\mathcal{Z}_1+\mathcal{Z}_2}{\mathcal{Z}_1+\mathcal{Z}_2}=1.732\,\underline{/\theta}$$

where θ may be any angle. Figure 2 illustrates one such circuit.

When a circuit is composed of unbalanced self- and



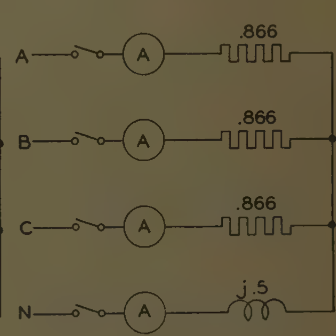
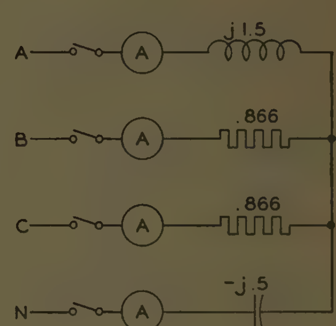


Figure 1 (above, left).

Figure 2 (above, right).

Figure 3 (right).



mutual impedances, the impedances can be resolved into symmetrical components although the impedances are complex numbers, and not rotating vectors as are 3-phase voltages and currents. Their sequence components will not be the same for different reference phases of current, and there will be mutual coupling between sequences. This means, of course, a larger number of design constants that appear in equations relating voltages and currents. For example, the circuit of Figure 3 relates the symmetrical components of voltage drops and currents by the following equations:

(a). For phase a:

$$E_0=1.154\, I_0\, \underline{/300^\circ}+0.577\, I_1\, \underline{/120^\circ}+0.577\, I_2\, \underline{/120^\circ}$$

$$E_1=0.577\, I_0\, \underline{/120^\circ}+0.765\, I_1\, \underline{/41^\circ}+0.577\, I_2\, \underline{/120^\circ}$$

$$E_2=0.577\, I_0\, \underline{/120^\circ}+0.577\, I_1\, \underline{/120^\circ}+0.765\, I_2\underline{/41^\circ}$$

(b). For phase b:

$$E_0=1.154\, I_0\, \underline{/300^\circ}+0.577\, I_1\, \underline{/240^\circ}+0.577\, I_2$$

$$E_1=0.577\, I_0 \qquad +0.765\, I_1\, \underline{/41^\circ}+0.577\, I_2\, \underline{/240^\circ}$$

$$E_2=0.577\, I_0\, \underline{/240^\circ}+0.577\, I_1 \qquad +0.765\, I_2\, \underline{/41^\circ}$$

(c). For phase c:

$$E_0=1.154\, I_0\, \underline{/300^\circ}+0.577\, I_1 \qquad +0.577\, I_2\, \underline{/240^\circ}$$

$$E_1=0.577\, I_0\, \underline{/240^\circ}+0.765\, I_1\, \underline{/41^\circ}\ +0.577\, I_2$$

$$E_2=0.577\, I_0 \qquad +0.577\, I_1\, \underline{/240^\circ}+0.765\, I_2\, \underline{/41^\circ}$$

It will be found that this circuit has the property of drawing the same current through the switches and ammeters when any two or all four switches are closed.

The question is: Can a linear static circuit be designed that will draw the same current through the ammeters when any two, any three, or all four switches are closed?

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Answers to Previous Essays

Delta Network. The following is the author's answer to his previously published essay of the foregoing title (*EE, June '50, p 550*).

All three statements are true.

1. The sum of the three delta impedances is zero, and the three star-connected impedances must be real and infinite. Z_a is negative, while Z_b and Z_c are positive. Such a circuit is an obvious impossibility.

2. When the circuit is connected to a source of balanced 3-phase voltage, the following values of voltage and current are readily computed:

$$E_a=1\, \underline{/90^\circ};\quad E_b=1\, \underline{/330^\circ};\quad E_c=1\, \underline{/210^\circ}$$

$$E_{ab}=E_a-E_b:$$

$$E_{ab}=\sqrt{3}\, \underline{/120^\circ};\quad E_{bc}=\sqrt{3}\, \underline{/0^\circ};\quad E_{ca}=\sqrt{3}\, \underline{/240^\circ}$$

$$I_{ab}=E_{ab}/Z_{ab}:$$

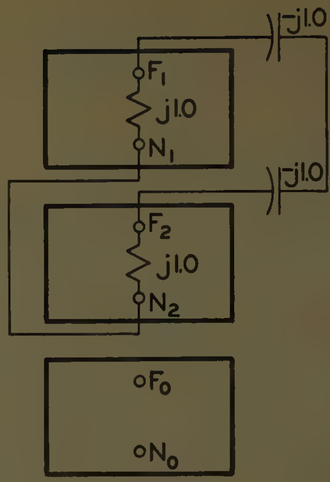

Figure 1

$$I_{ab}=\sqrt{1/3}\, \underline{/30^\circ};\quad I_{bc}=\sqrt{1/12}\, \underline{/90^\circ};\quad I_{ca}=\sqrt{1/3}\, \underline{/150^\circ}$$

$$I_a=I_{ab}-I_{ca}:$$

$$I_a=1;\quad I_b=-{}^1/_2;\quad I_c=-{}^1/_2$$

When one of the line connections is broken, the circuit is found by inspection to be a tuned parallel LC circuit with respect to the other two lines which presents an infinite impedance to single-phase voltages impressed on any one pair of its terminals.

3. The capacitor $-j6$ can be replaced by a capacitor $-j2$ and a reactor $j3$ connected in parallel with it. The network then can be represented by three reactors $j1$ connected in star, and a capacitor $-j2$ connected to terminals b and c. The star-connected reactors will appear in the sequence networks of the system as shunts $j1$ across the positive and negative sequence networks. The capacitor $-j2$ is connected from line to line and will appear as two capacitors $-j1$ connected in series between the F_1 and F_2 terminals of the networks. Terminals N_1 and N_2 are connected to each other. This connection is illustrated in Figure 1.

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Magnetized Iron, Stretched or Swelled? The following is the author's answer to a previously published essay of the foregoing title (*EE, June '50, pp 550–1*).

You are getting a bit tiresome, Alter Ego, with your concern about the ponderomotive forces per unit volume inside matter due to electric or magnetic fields. By this time your readers are quite well aware that there is no uniquely valid or observable electrical or magnetic ponderomotive force within matter. They know that physicists will give different values for their ponderomotive force per unit volume with the related surface force, but that they won't let you observe their individual ponderomotive force densities by any experiment, because for a complete body surrounded by empty space, they will all integrate their forces up to give the same actually observable total force.

However, your idea about making cuts with a hacksaw is a good one because it gives me a chance to talk about Maxwell's stress tensor, and also show you how to invent as many new and all equally valid force densities as there are physicists, with enough left over to take care of the generations of physicists to come.

Figure 1. Inside matter

I shall limit my remarks to the case of the action of steady electric fields acting upon perfectly insulating bodies or dielectrics, at rest. The ideas can, however, be carried out in the more general case. I shall also, for economy of words, neglect gravitational action.

Consider a body at rest in empty space. For such a body Maxwell has given a method for determining from a knowledge of the electric field outside the body the total electric force, and that is the honest-to-goodness mechanical force which must be applied to keep it at rest.

We consider a surface enclosing the body. Then the total electric force $\mathbf{F}$, acting on the body, and which balances the mechanical force, is given by the following integral over the surface,

$$\mathbf{F}=\frac{1}{8\pi}\int\int(2\,\mathbf{E}\,\mathbf{E}\cdot d\mathbf{S}-E^2 d\mathbf{S}) \tag{4}$$

The x, y, and z components of F are

$$F_x=\frac{1}{8\pi}\int\int(E_x^2-E_y^2-E_z^2)dS_x+2E_xE_ydS_y+2E_xE_zdS_z \tag{5}$$

$$F_y=\frac{1}{8\pi}\int\int 2E_xE_ydS_x+(E_y^2-E_z^2-E_x^2)dS_y+2E_yE_zdS_z \tag{6}$$

$$F_z=\frac{1}{8\pi}\int\int +2E_xE_zdS_x+2E_yE_zdS_y+(E_z^2-E_x^2-E_y^2)dS_z \tag{7}$$

The coefficients of dS_x, dS_y, and dS_z in equations 5 are called the components of Maxwell's stress tensor.

We may apply Gauss's theorem to any one of the foregoing surface integrals. For example we might take that for F_x but start with the more convenient form derived from equation 4, with $\mathbf{i}$ the unit vector in the x direction

$$F_x=\frac{1}{8\pi}\int\int 2E_x\mathbf{E}.d\mathbf{S}-E^2\mathbf{i}.d\mathbf{S}$$
$$=\frac{1}{8\pi}\int\int\int \text{div}\,(2E_x\mathbf{E}-E^2\mathbf{i})dT \tag{8}$$

We may then interpret the integrand in the volume integral as the x component of a force per unit volume, since it integrates up to the correct total F_x. In this case the integrand

$$\frac{1}{8\pi}\text{div}\,(2E_x\mathbf{E}-E^2\mathbf{i})=\frac{1}{4\pi}E_x\,\text{div}\,\mathbf{E}=[f_B]_x \tag{9}$$

That is, we get the electric volume force of Bill, (*EE, May '50, pp 456–7*). It gives zero volume force in empty space as it should, and Bill's surface forces on surfaces where $\mathbf{E}_n$ is discontinuous.

But now in applying Gauss's theorem, we do not need to use precisely the tensor suggested in the equations 5, 6, and 7. We may use any nine functions we may please which can serve as components of a tensor, provided these nine functions in empty space, that is where $\mathbf{D}=\mathbf{E}$, reduce to the tensor components of Maxwell for empty space, that is, the nine functions given in equations 5, 6, and 7. For example we may use

$$F=\frac{1}{8\pi}\int\int 2\mathbf{E}\mathbf{D}\cdot d\mathbf{S}-E^2d\mathbf{S} \tag{4$'$}$$

which gives

$$F_x=\frac{1}{8\pi}\int\int(2E_xD_x-E_x^2-E_y^2-E_z^2)dS_x+2E_xD_ydS_y+2E_xD_zdS_z \tag{5$'$}$$

and so forth.

It is clear that equation 4′ reduces to equation 4 when applied over a surface lying in empty space, so equations 4′ and 4 must agree as to what the force is on the body which the surface encloses. However, if we apply Gauss's theorem to equation 5′, and so forth, we get with a little mathematical manipulation for the volume force, $\mathbf{f}=\rho\mathbf{E}+\mathbf{P}\cdot\nabla\mathbf{E}$ which is Charlie's formula. Thus Charlie will always agree with Bill as to what the total force is on a body surrounded by empty space. Suppose now we take

$$\mathbf{F}=\frac{1}{8\pi}\int\int 2\mathbf{D}\mathbf{D}\cdot d\mathbf{S}-\mathbf{D}^2d\mathbf{S} \tag{4$''$}$$

which also agrees with equation 4 for any surface in empty space.

Again applying Gauss's theorem, and with a little mathematical manipulation, we get for the volume force, $\mathbf{f}=\frac{1}{4\pi}\mathbf{D}\,\text{div}\,\mathbf{D}-\frac{1}{4\pi}[\mathbf{D}\times\text{curl}\,\mathbf{D}]$, which, when translated over to the magnetic case, gives the formula of Jack. Hence Jack also will agree with Bill and Charlie as to the total force on a body in empty space, even though he disagrees as to the force per unit volume within the body.

Equations 4′ and 4″ are examples of expressions which define tensors which reduce to Maxwell's tensor in empty space. It should be clear how to write as many others as one may wish.

Now how about the force on a volume which is completely inside matter? Well, what can we do other than what Alter Ego suggested? How else can we tell whether a given formula for the force is correct except to apply Alter Ego's hacksaw test and cut the volume away from the rest of the material so that the force can be observed. But after we do that, the volume V lies in empty space (Figure 1), a thin shell perhaps, but nevertheless an empty space in which we may place an enclosing surface S and apply Maxwell's stress tensor, equation 4. Then as before, instead of Maxwell's stress tensor we may use any of the infinitely many tensors which reduce to Maxwell's in empty space, and still correctly calculate the force of the cutaway volume.

We conclude then that there is no uniquely valid or correct formula for the electric force on a volume inside matter. Infinitely many different formulas may be devised which will all meet the test of any experiment successfully.

J. SLEPIAN (F '27)
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District Papers Digested for Great Lakes District Meeting

These are authors' digests of most of the District papers presented at the AIEE Great Lakes District Meeting, Jackson, Mich., May 11–12, 1950. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings, nor are they available from the Institute.

Application of Motors and Control to Air Compressor Drive; *G. F. Johnson (Joy Manufacturing Company, Michigan City, Ind.).*

The following considerations enter into the selection of motors for compressor drive:

1. Rated power required by compressors.
2. Ventilation of compressor room.
3. Type of compressor drive.
4. Type of motor available.
5. Flywheel effect.

Since the maximum power seldom exceeds the normal full-load horsepower of a compressor, motors should be selected with a name-plate horsepower approximately the full-load horsepower required of the compressor. The allowable temperature rise of the motor winding will permit small overloads that may be encountered as a result of poor discharge pipe arrangements, and so forth. Air compressors generate heat when compressing, and in a poorly ventilated area the ambient temperature may be raised sufficiently to cause injurious heating of the motor.

General-purpose motors are used for *V*-belt-driven and direct-connected compressors. In order to conserve space and reduce line-up problems, close-coupled or flange-mounted motors may be preferred.

Squirrel-cage motors are given first consideration because of low first cost and low maintenance, while synchronous motors are chosen for installations where the improved plant power factor warrants the increased investment.

The rotor serves as the compressor flywheel on flange-mounted and coupled units. On this type of unit the manufacturer must determine if added WR^2 is required in the rotor for adequate flywheel effect.

Full voltage starting is used to as high a rating as the power system and plant policy will permit. Magnetic starting equipment is required whenever it is desired to have the compressor controlled automatically by a pilot device or from a remote location.

Commutation in Universal-Type Motors; *L. C. Packer (Westinghouse Electric Corporation, Springfield, Mass.).*

The problem of commutation in Universal-type motors has always been one of the most important problems in satisfactory operation on direct and alternating current. The many factors influencing satisfactory commutation are the electrical, magnetic, mechanical condition of the armature, carbon brush, and, in some applications, the atmospheric conditions.

On both alternating and direct current the armature conductors cutting across the magnetic field set up by the combined armature and field windings generate three voltages in the armature coils short-circuited, by the brushes, in the commutating zone. One of these voltages is due to the magnetic field in the space between the poles, another is due to the flux which crosses from slot to slot, and another is due to the flux set up in the armature end winding. These reactance or rotational voltages are directly proportional to the flux cut by the armature conductors, revolutions per second, and the number of armature turns in series in the short-circuited coil.

When the motor is operated on alternating current there is also a transformer voltage due to the whole main flux passing through the armature coil while it is short-circuited. This voltage is directly proportional to the total main field flux, the frequency of the circuit, and the turns in the short-circuited coil. It is 90 degrees out of phase with the field flux and its value is independent of the speed of the armature and is much greater than the total rotational voltages.

The rotational voltages are in phase with the field flux and are 90 degrees out of phase with the transformer voltage in the short-circuited coil and cannot in any way affect the value of the transformer voltage.

The resultant short-circuit voltage is the vector sum of the transformer voltage and the total rotational voltages.

A ratio of armature to field ampere-turns of 0.7 to 0.8 and the brushes shifted 20 to 26 degrees against rotation usually gives satisfactory performance for noncompensated motors. Good armature balance, proper brush application, and good mechanical conditions are assumed in all commutating problems.

In one type of compensated motor there is a winding distributed at 90 degrees to the main field and in series and opposing the armature field. In another type there is a single distributed field winding with the brushes moved back against rotation a predetermined amount which compensates for the armature field.

Application of Magnetic Amplifiers; *F. N. McClure (Westinghouse Electric Corporation, East Pittsburgh, Pa.).*

Magnetic amplifiers are being increasingly used as components in all sorts of control and regulating circuits. Today, engineers are uncovering potential uses for these static amplifiers in practically every electrified industry in the United States.

Although the simple saturable-core reactor has been known and applied for years, the renewed interest in the use of magnetic amplifiers can be attributed to three main factors: First, the self-saturating circuit, which makes possible high values of power gain, was very little used and certainly not generally understood in prewar applications of magnetic amplifiers. Second, the performance of self-saturating magnetic amplifiers depends greatly on the core materials and rectifiers used. The recent developments in core materials and dry-type rectifiers have made it possible to capitalize on the self-saturating circuits. Third, industry is ready for such a device. Electronic control in industry is very well established. However, certain applications stand out where an amplifier would be more practical if it were permanent and maintenance-free.

The effective application of modern magnetic amplifiers in industry depends upon a clear understanding of the operation of the self-saturating circuit, characteristics of core materials and rectifiers, and performance characteristics of the complete magnetic amplifier.

Magnetic amplifiers are being used in a wide variety of applications. However, they should not be considered as a cure-all for control and regulating problems, but rather as a new tool for application engineers.

Voltage Regulation of Suburban and Rural Feeders; *W. L. Peterson (Allis-Chalmers Manufacturing Company, Milwaukee, Wis.).*

A yearly economic return of as high as 90 per cent on the investment of pole-type regulators for voltage improvement can be realized. Proper utilization voltage is one phase of any load building program and in addition offers greater economy in the modern distribution system.

For instance, during the war years, one operating company reported a 10-per cent reduction in bus voltage resulted in a 15-per cent reduction in load on commercial and residential feeders. This was an emergency measure for which there is no need today. Yet there are distribution systems serving utilization voltages below 115 volts rather than the required 120 volts.

In the past, the distribution engineer was limited in the number of possible solutions to the low-voltage problem for small blocks of power. The larger blocks of power may be regulated economically, but the distribution circuit may need further voltage improvement in outlying territories of the system some distance from the substation. In the past few months, pole-type regulators have been made available at less than \$4 per kilovolt-ampere of regulation or on a par with station-type regulators. The regulator has plus and minus 10-per cent regulating range in 32 $^5/_8$-per cent steps and in every way meets the quality of voltage regulation of the station-type regulator.

In the application of the pole-type regulator to the rural line, it is desirable to obtain the voltage profile of the line and project the profile to the condition which gives a 10-volt drop beyond the minimum allowable voltage. The regulator should be located at the point where the voltage profile drops below the minimum allowable voltage.

There is a definite possible use for pole-type regulators in the modern, urban distribution system. In the primary mains and laterals, there is usually a maximum allowable voltage drop of three volts between the first and last distribution transformers. These primary mains and laterals run many hundreds of feet and a 3-volt drop may not permit economical use of the con-

ductor. The pole-type regulator offers the distribution engineer a new tool to make greater use of the existing copper in these mains and laterals by adding more loads to the existing distribution system. The use of pole-type regulators on urban distribution systems is an innovation, but it has possibilities for the distribution engineer to investigate.

Problems in Design and Application of Large Turbine Generators; *A. A. Johnson, M. D. Ross* (*Westinghouse Electric Corporation, East Pittsburgh, Pa.*).

For turbine generators of 100 megawatts and larger two limiting factors affect the selection of stator voltage. The first is design conditions relative to combinations of slots, throw, economical flux density, and so forth, which determine voltage rating. The second is that 6,000 amperes per terminal bushing seems to be a top limit for current capacity. The most economical voltages and ratings are about as follows:

	1,000 Rpm	3,600 Rpm
13.8-kv single winding	up to 110,000 kva	up to 110,000 kva
16.5-kv single winding		110,000 to 130,000 kva
13.8-kv two windings	110,000 to 200,000 kva	
16.5-kv two windings		130,000 to 176,000 kva

The 3,600-rpm generators weigh less and take less floor space than the same ratings of 1,800-rpm units. Two-winding generators at 3,600 rpm can be built at lower and higher ratings than those indicated.

With improved insulating materials for generator windings, voltages up to about 27 kv are being considered. Voltages above 22 kv probably will be considered only in those cases where it is desired to connect a large generator to an existing distribution bus. A single-winding or 2-winding generator can be connected either to existing busses at generator voltage or through step-up power transformers to a high-voltage bus. A 2-winding machine might be desired where space is available for only one machine, but where it is desired to supply power to two existing busses.

The application of 2-winding generators requires more planning and analysis than do single-winding units. The load on the two windings must be balanced within the ratings of the windings. The connection to the system involves two circuits through some arrangement of circuit breakers or transformers or both. The calculation of short-circuit currents supplied to a system by one winding of a 2-winding generator is quite involved because of the contribution of the system connected to the unfaulted winding and because of saturation in the stator teeth of the generator. The short-circuit current supplied by a single winding usually is considerably more than half of the current which would flow if both windings were short-circuited simultaneously. In those applications where one winding can be disconnected from the system with the other winding carrying load, the voltage on the open winding may be as much as 8 to 15 per cent above the voltage on the winding in service, depending upon the generator characteristics. Other problems are: voltage regulation, surge protection, minimum excitation control, differential relay protection, grounding, and so forth, each of which requires special consideration for each application.

Whether a generator is single winding or double winding, a series reactor should be placed between the generator terminals and the bus, where the bus has distribution feeders, to limit the magnitude of generator current supplied to system faults and also to assist in providing better generator surge protection. While each generator is designed to withstand a momentary 3-phase fault at its terminals under all operating conditions, it is considered good practice and safer for long life of generator windings and insulation to limit the severity of the short circuits.

High-Voltage Generator Insulation; *Graham Lee Moses* (*Westinghouse Electric Corporation, East Pittsburgh, Pa.*).

A new electrical insulation is being applied to central station sizes of turbine generators. This new insulation has such outstanding electrical, physical, and chemical properties that it is replacing conventional asphalt-bonded mica insulation on large turbine generators employing half-coil construction.

Industry demand for larger and larger concentrations of generating capacity in single units has accelerated the development of this improved insulation. With ever-increasing sizes of turbine generators, the major problem has been to accommodate differential expansion of copper, iron, and insulation on very long stator windings. This problem has been solved with the new Thermalastic insulation by keeping mica, which is proved by half a century's experience, and adapting it to the industry's present and future needs. A solid yet resilient bond and impregnant has been substituted for the rigid brittle shellac bond first used and for the plastic asphalt bond used for over two decades prior to 1950. The resultant composite insulation has outstanding properties in many other respects. Its dielectric strength and voltage endurance are both excellent, its thermal endurance is high, and its physical characteristics represent significant improvement over conventional insulations.

The coils are insulated from ground by multiple layers of continuous mica tape. The newly developed mica tape used is bonded with a synthetic resin with excellent electrical properties. The mica tape is applied dry without employing brushing bond. The process requires no multiple intermediate impregnations as all the tape is applied before impregnation. The coil is taped over-all with a fiber glass tape for binding and finishing.

The coils are treated at high vacuum to remove moisture, solvents, and gases. They are then impregnated under pressure with a newly developed solventless thermosetting synthetic resin varnish of low viscosity. The process used results in the greatest practicable fill of the coil interstices. After impregnation, the resin is cured by heating while there is physical restraint of the insulation both on the straight part and the end winding. This processing results in a high degree of filling and excellent consolidation. The resultant composite insulation is a tough yet flexible dielectric barrier with excellent electrical thermal and physical properties. The insulation is strong yet elastic and possesses good dimensional stability.

This Thermalastic insulation offers promise of even greater reliability for some classes of high-voltage generators. Its outstanding characteristics have led to its adoption as the standard insulation for all Westinghouse turbine-generator stator windings employing half-coil construction, which includes those rated at 12,500 kva and larger.

Progress Report of Utilities Research Commission Investigation of Galloping Conductors; *E. L. Tornquist, F. E. Andrews* (*Public Service Company of Northern Illinois, Chicago, Ill.*).

Galloping of overhead line wires is a phenomenon of harmonic motion resulting from instability caused by aerodynamic forces on the wires, usually when covered with ice. Presently available practical methods of avoiding trouble from galloping are to provide sufficient clearance between wires to avoid contact, with design adequate to withstand the stresses, and to deice the conductors by means of current sufficient to raise the temperature high enough to melt the ice.

The Utilities Research Commission, representing the Commonwealth Edison group of companies, has been working actively on the galloping conductor problem since 1944. The earlier work was covered in an AIEE paper in 1947 by Tornquist and Becker (AIEE *Transactions*, volume 66, page 1154). A full-scale experimental line with wires equipped with air foils was built which would gallop in ordinary winds without ice. This was used for study of the causes of galloping and for investigation of damping arrangements. Concurrently arrangements were also made for certain phases of the problem to be studied by Dr. Charles O. Harris, then at Notre Dame University. He conducted wind tunnel experiments and obtained the lift and drag values for an air foil section similar to that used on the experimental line. From these data he was able to draw curves that expressed the net aerodynamic energy that the line would absorb from the wind. These were expressed in dimensionless parameters that permit a visualization of the energy input to the line at various amplitudes for a right angle wind.

Conferences with recognized authorities in the field of aerodynamics and vibration as well as our own work, have indicated that the principle of energy absorption provides a sound basis for developing a means of mitigating damping. Experimental dampers operating on this principle have been built and are undergoing test. Favorable preliminary test results have been obtained from galloping with natural ice and also with the experimental line equipped with foils. It is planned to continue the work to include

a more satisfactory evaluation of the effects of oblique wind, to obtain information on the inherent damping characteristics of the line itself including supports, and to develop simpler and more effective damper designs.

Design and Construction of 69-Kv Transmission Structures; *Ralph G. Yerk (Hughes Brothers, Seward, Nebr.)*.

During the studies relative to a standard design for a 69-kv transmission structure for utilities operating in medium- or low-density areas and extensive transmission, it was apparent that where right-of-way costs were not prohibitive, an H-frame line could be built more economically than a single-pole line. It further developed that an H-frame line suitable for future conversion to higher voltage can be erected at a very slight additional cost. The savings in H-frame construction results from the necessity of fewer structures, and H frames usually are more adaptable to rolling terrain where advantage of the longer spans can be realized. Of the six basic designs for single-pole construction, two of the more modern designs are mechanically and electrically a practical solution because of greater phase spacing, better shielding, and are less susceptible to outages due to dancing conductors. Studies further indicate that the smallest conductor does not usually result in the most economical over-all line costs.

Increasing the Voltage of a Subtransmission Network From 24 Kv to 40 Kv; *Philip Holz, G. A. Strohmer (The Detroit Edison Company, Detroit, Mich.)*.

When rapidly increasing loads in the "Thumb" of Michigan required increased transmission capacity, the voltage on the subtransmission network serving the area was changed from 24 kv to 41.6 kv. The numerous small transformer banks, with 25-kv insulation, serving distribution load were reconnected from delta-delta to Y-delta and operated at 40 kv. Much of the line insulation, designed for 24 kv, was also retained along with the oil circuit breakers and some other equipment.

The nature of the network made it possible to use a rather unusual scheme of protection against transient overvoltage and short circuits. Lightning arresters rated 30 kv were chosen to protect the 25-kv transformers. The neutrals of many selected transformer banks were grounded to limit transient overvoltage to this lightning arrester rating. These transformer banks, including many tapped on lines, were protected by high-side phase and neutral fuses. Neutral fuses, selected to protect the transformers against transformer faults, were in turn protected against blowing for line faults by setting ground relays to trip the line circuit breakers before the neutral fuses could be damaged. Although many extremely fast and sensitive ground relay settings were used, selectivity between ground relays was excellent.

Operating experience has been good over a period of ten years. There has been no excess of radio interference complaints or equipment failures nor has the type of failures indicated that they were due to excessive voltage. No lightning arresters have failed.

Transmission Substation Design—A Departure From the Usual; *E. V. Sayles (Consumers Power Company, Jackson, Mich.)*.

There is continuous need for the examination of current substation designs if low investments are to be secured. Several new features have been adopted to secure low costs for a system requiring some 600,000 kva in transmission substations and the normal addition of about 130,000 kva in transmission substation capacity each year. New developments include the use of a standardized set of structural parts with which any type of outdoor substation structure can be assembled. These parts consist of lengths of rigid trusses and other structural pieces so fabricated with matching holes that they can be readily fitted together. There are about 100 different standard parts which are regularly used for all substation construction regardless of size, voltage, or bus arrangements. In addition, there is a new type of overhead conduit system which totally eliminates underground conduits in all large transmission substations. The system provides for the use of unit control houses in each substation bay and a small central control house containing a miniature switchboard console which permits an operator to take certain readings and operate certain switches, although the majority of these substations are fully automatic.

Chemical Brush Control on Rural Power Systems; *C. J. Waldron (United States Department of Agriculture, Rural Electrification Administration, Washington, D. C.)*.

The use of herbicides to control the growth of woody plants offers a method of clearing to many rural power systems that is proving more economical and effective than other methods. The herbicides generally used for brush control include ammonium sulfamate, 2,4-D (2,4-dichlorophenoxyacetic acid), and 2,4,5-T (2,4,5-trichlorophanoxyacetic acid).

Applications of herbicides are generally made during the growing season by spraying the foliage with gasoline-engine-driven power sprayers, equipped with tank, hose, and suitable boom or spray gun, mounted on trucks or trailers. The usual pressure for foliage spraying is 150 or 200 pounds per square inch. However, it varies among individual users from 50 to 600 pounds per square inch.

Ammonium sulfamate is applied at the rate of three-fourths or one pound of chemical per gallon of water. The majority of users apply solutions of 2,4-D and 2,4,5-T in strengths between 3,000 and 4,000 parts per million. On brush of average density, six feet tall, 125 gallons of solution per acre is a typical rate.

Stump sprays are also used; concentrated solutions of 2,4-D and 2,4,5-T mixed with diesel oil or kerosene, or ammonium sulfamate in water being applied with knapsack sprayers.

Serious obstacles to the use of growth regulating herbicides in cotton growing regions are damage by drift and, to a lesser extent, by volatilization to crops near the right-of-way sprayed. Other susceptible plants include tobacco, tomato, potato, legumes, grapes, fruit trees, and many flowers and ornamental shrubs and trees.

A single application of 2,4-D and 2,4,5-T in water, sprayed on the foliage of a mixed woody plant population, often results in a kill of 80 per cent. Spot spraying is usually necessary one or two years after the first spray and again in the fifth year. Except where there is a large percentage of species hard to kill, these sprays, followed by a fourth spray in the tenth year, are expected to accomplish an acceptable degree of control.

Much research is being done with chemicals for brush control. Better penetrants are being sought to make herbicides more effective. The effect of atmospheric conditions, stage of growth of the plant, soil moisture and type of soil, and amount of chemical necessary to kill a plant are being studied. Experiments are being conducted with applications of chemical to only the base of plants and with sprays applied to plants not in active growth.

Noise Evaluation of Fluorescent Lamp Ballasts; *C. P. Hayes, H. R. Gould (General Electric Company, Fort Wayne, Ind.)*.

Noise testing of fluorescent lamp ballasts has been studied from a number of approaches. A system has evolved from these studies which, if acceptable to the industry, may provide a basis for industry specifications and standards regarding this type of measurement.

The primary purpose of developing this measurement system was to obtain a realistic noise quality number which would define the noise characteristics of any fluorescent ballast. The noise test assembly consists of a special dummy fluorescent fixture, a collecting horn, and a standard General Electric sound level meter. The fluorescent ballast is mounted on the top surface of the dummy fixture during the noise test. Several variables have been encountered which must be carefully controlled in this test. These include ballast mounting, ballast temperature, and lamp operating temperature.

This fluorescent ballast test has had several important applications. It has been a valuable tool for evaluating possible methods for reducing ballast noise. It is suitable for quality sampling tests, but it is too lengthy for a 100-per cent production noise test. This measurement system is by no means perfect, and it is hoped that others will try this system so that further improvements may be possible. It is believed that this measurement system has been developed far enough to be considered by others who are concerned with the problems of noise and its measurement.

Digests of Papers Presented at Conference on Telemetering

These are authors' digests of most of the papers presented at the Conference on Telemetering, sponsored by the AIEE and the National Telemetering Forum, in Philadelphia, Pa., May 24–26, 1950. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings. However, they will be made available in a consolidated report of the conference which may be obtained for $3.50 from AIEE Headquarters, 33 West 39th Street, New York, 18, N. Y.

Historical Highlights in Telemetering; *Perry A. Borden (The Bristol Company).*

The basic concepts of electrical telemetering are surprisingly old, and may almost be said to be contemporary with those of the electric telegraph. The line of demarcation between telemetering and telegraphy is indefinite, but can be considered as involving the presence or absence of a quantitative relationship adaptable to the purposes of measurement. Perhaps the earliest recorded communication method which could be looked upon as having any equivalency to telemetering is found in a telegraph system developed and operated in England about 1823. This utilized a "scanning" principle in which individual letters were successively picked out by means of a synchronized transmitter and receiver. As might be expected, the weak point lay in the impossibility of maintaining synchronism between the two stations.

"Duplicate position" methods of telemetering appear to have had their prototype in the Siemens deflecting telegraph patented in England just 100 years ago. Telemetering by means of timed electric signals was suggested as early as 1854; and 20 years later there was published a description of a "radiosonde" in which such signals were transmitted from a captive balloon to a ground station over wires in rubber tubes.

Inductive adjustment of an interrupted current for telemetering is shown in a patent issued in 1889; and the positioning of a rheostat by a Bourdon tube in 1904. The bridge circuit was applied to the purpose as early as 1894. "Position motors" as exemplified in the "Selsyn" appeared about 50 years ago, and were first extensively used in America on the Panama Canal installation about 1914. A "frequency" system, involving variable-speed alternators, was included in the electrification of the Chicago, Milwaukee and St. Paul Railroad over 30 years ago; but the use of frequency variation for telemetering purposes really came into its own with the general adaptation of the electron tube in measurement and control circuits about 1926. The thermal converter, producing a unidirectional electromotive force suitable for both telemetering and totalizing of electric power loads, while fully described in United States patents issued in 1890, was lost sight of until about 1925, when a small installation was made in England. The earliest extensive application of the principle on this continent was in the totalization of a large Canadian power load in 1926.

The AIEE Subcommittee on Telemetering was first formed in 1927, under the aegis of the Committee on Instruments and Measurements. This group, including also members from the Committee on Automatic Stations, sponsored a Report on Telemetering and Supervisory Control, published in 1932. After several revisions, this report appeared in its present form in 1948.

Historical Sketch of the National Telemetering Forum and Mobile or Radio Telemetry; *W. J. Mayo-Wells (Applied Physics Laboratory, The Johns Hopkins University).*

Prior to World War II, radio or mobile telemetering was largely connected with radiosondes and meteorological experiments, the earliest recorded use being found in France. Today, mobile telemetering is the life-blood of the guided missile and rocket flight research programs, and has attained an equal status with other groups planning these tests. It has also been adopted for many industrial purposes.

To promote the free and unselfish exchange of technical information among all organizations engaged in this telemetering field, and to provide a common meeting ground for those setting forth the "requirements" and for those producing the "availabilities," the National Telemetering Forum was established in the spring of 1948. During its 12 meetings, a wide diversity of interests have been brought together, subject only to military clearance, and great benefits have resulted from the information made known on all phases of the mobile telemetering art. Full liaison has been maintained with AIEE and other national societies. The principles of the forum are applicable to many other fields, and their employment should prove equally advantageous in forwarding the national defense program.

Mobile telemetering has developed along two major lines: using FM/FM* technique; and using pulse system techniques. Recently the Radio Defense Board has been able to obtain agreement on a standard FM/FM specification, both for air-borne and ground systems.

In the course of these developments two schools of thought have arisen in the mode of application of mobile telemetering for air-borne installations. One favors the employment of fixed-design units with restricted inputs and size characteristics. The other prefers to use a series of standard miniature subassemblies, from which building blocks an infinite number of systems can be assembled. Each of these systems can be designed to measure the exact required measurements with optimum efficiency.

* Radio telemetering is catalogued by the mode of transmission and designated by the usual initialled abbreviations: FM, frequency modulation; AM amplitude modulation; PM, pulse modulation, and so forth.

Radio-Telemetering Methods and Terminology; *John F. Brinster (Applied Science Corporation of Princeton).*

This paper was intended to provide a discussion of the basic differences between radio- and wired-telemetering methods. Particular attention was given to radio-telemetering principles. Basic requirements were pointed out as:

1. A multitude of channels.
2. Relatively high-frequency response in each channel.
3. Minimum physical size.
4. Highly mobile operation with fixed recording stations.

Features peculiar to radio links which provide the large difference and govern the choice and limitations of multichannel radio telemetering methods were described as:

1. Noise is introduced together with the desired signal.
2. The desired signal experiences nonlinear distortion.
3. The frequency spectrum of the desired signal is limited and modified.

Specific methods of transmitting a multitude of data over a single radio link were discussed according to their main classifications and subdivisions thereof.

Time-division and frequency-division methods were described as the principle divisions. Particular modulation methods in both categories were discussed in standard terminology including:

Frequency-Division Methods:

AM–AM, Amplitude-modulated subcarrier on an amplitude-modulated carrier.

FM–AM, Frequency-modulated subcarrier on an amplitude-modulated carrier.

AM–FM, Amplitude-modulated subcarrier on a frequency-modulated carrier.

FM–FM, Frequency-modulated subcarrier on a frequency-modulated carrier.

Time-Division Methods:

PAM–AM, Pulse amplitude modulation on an amplitude-modulated carrier.

PAM–FM, Pulse amplitude modulation on a frequency-modulated carrier.

PDM–FM, Pulse duration modulation on a frequency-modulated carrier.

PPM–AM, Pulse position modulation on an amplitude-modulated carrier.

PCM–AM, Pulse code modulation on an amplitude-modulated carrier.

Telemetering in a Large Interconnected Power System; *C. K. Duff (Hydro-Electric Power Commission of Ontario).* Interconnected power systems in Southern Ontario and adjacent areas are used to illustrate applications of telemetering in power system operation. In local plant operation, regional operation, and system operation, telemetering has specific functions for labor-saving purposes, for improvement in efficiency, and as a necessary link in automatic load and frequency control without which extensive interconnected operation would not be feasible.

Typical applications are cited for telemetering equipments of the five basic types. For system supervision and control, telem-

etering must span long distances with a high degree of accuracy, reliability, and speed of response, since telemetering is a link in a closed-loop automatic control system.

To the system operator's office in Toronto there are telemetered at present the loads of three tie lines, two frequency-changer stations, and five generating stations, with more to be added in the near future. Automatic load-frequency controllers in this office regulate generation of the 25-cycle and 60-cycle divisions of Southern Ontario to maintain frequency and tie-line loads. The longest telemetering route is 300 miles, with one relay station en route.

Telemetering channels used are wire circuits in cable up to 20 miles distance, carrier on Commission-owned open-wire telephone lines up to 100 miles, and carrier on 115-kv and 230-kv power lines up to 200 miles or more. Telephone-line carrier telemetering has been used since 1942, but is somewhat vulnerable to bad weather conditions. The Commission's first installation of power-line carrier telemetering was recently placed in service. Space radio is being tried experimentally over a 23-mile line-of-sight route with encouraging results.

Telephone-line carrier and power-line carrier used for load control and telemetering in Southern Ontario now total 2,640 channel-miles, with extensive additions of power-line carrier under way.

Bumblebee FM/FM Telemetering System; *J. W. Hamblen* (*Applied Physics Laboratory, The Johns Hopkins University*).

The design of the Bumblebee FM/FM telemetering system has been based on the test vehicle requirements of ruggedness, compactness, and accuracy.

The present basic air-borne system employs ten subcarrier oscillators, the outputs of which are combined and fed into a frequency-modulated very-high-frequency transmitter. By appropriate choice of individual components or combinations of components, a telemetering equipment may be assembled which will best measure the particular functions in question. To provide more than ten channels of intelligence, commutation of oscillator outputs and/or inputs may be employed.

The telemetering ground station consists of: a frequency-modulated receiver; a set of band-pass filters; a set of audio discriminators; a multichannel oscillograph; a secondary audio-frequency standard. The receiver output voltage is a reproduction of the composite voltage impressed upon the input of the reactance modulator in the missile transmitter. This output voltage is applied to a bank of discriminator units which have two functions: to separate the subcarrier frequency bands; and to convert the varying frequencies into varying direct voltages.

The data reduction procedure consists of three fundamental steps:

1. A record calibration curve is prepared by combining the discriminator calibration (trace displacement versus frequency) and the vehicle channel calibration (frequency versus telemetered quantity). This new calibration curve, therefore, indicates trace displacement as a function of the quantity under measurement.

2. The displacement of each trace from its fixed reference line is measured at all significant points throughout the length of the record. With reasonable care, the measurements can be made to an accuracy of 1/100 inch, providing the traces possess good resolution. The displacement representing bandwidth of a subcarrier band is approximately ±2 inches.

3. The displacement measurements are tabulated and plotted on graphs which show the variations in measured quantity against time.

Applications of Rectified Current to Telemetering on a 2-Conductor Circuit; *F. F. Uehling* (*Consulting Engineer*).

In the "Uehling Point-to-Point Half-Wave Telemetering System," the transmitter and receiver are interconnected by means of a 2-wire conductor, and energized by alternating current at any point along the conductor. By means of two rectifiers at the transmitter, the two half-waves of opposite polarity are separated, and their relative amplitude changed in proportion to changes in the magnitude of the measured variable thus creating a d-c component which, together with the a-c component, is carried over the 2-wire conductor to the receiver. Similar rectifiers are employed at the receiver where the two half-waves of opposite polarity are again separated and their relative amplitude brought back to unity by means of a servo or balancing mechanism controlled by the d-c component.

The Uehling Half-Wave Telemetering System thus utilizes a null-balance method which not only insures instantaneous response, but also eliminates the possibility of errors due to changes in the length or resistance of the 2-wire conductor which connects the transmitter with the receiver. A pointer or pen in geared connection with the balancing means will therefore indicate or record any change in the magnitude of the measured variable at the transmitter.

Telemeter Computing Systems for Industrial Process Functions; *A. J. Hornfeck* (*Bailey Meter Company*).

The remote indication or recording of process variables such as flow, liquid level, pressure, and temperature has been greatly facilitated by the use of instruments of the electronically operated null-balance type. Circuits for totalization, subtraction, multiplication, and ratio determination of these and other factors have been devised using basic components. A complete computing system for measurement and control of a process consists of a more or less complicated combination of any or all of these elementary calculating circuits.

The transmitter or transducer is generally a device which converts position or motion of the primary metering element into an electrical quantity such as voltage, current, resistance, impedance, or a ratio of these factors. Specific transmitters employed are the adjustable core or differential transformer and the resistance slidewire. The motor-driven follow-up in the null-balance system functions as the receiver and may be either of these devices, and in some applications both are used. The receiver and transmitter elements are arranged in a null-balance circuit of the bridge or potentiometer type. When the circuit is balanced, the follow-up will come to a position proportional to the desired function. By means of cam positioning of the follow-up, nonlinear relations such as exponentials are converted to linear factors to be indicated or recorded on uniform scales. These converted factors can then be retransmitted for the desired algebraic combination with other quantities.

The addition of automatic control to the computing receiver permits further mechanization of the process plant. Standard designs are available incorporating up to four continuously recording computer elements in a single-case instrument. Retransmitting elements for either pneumatic or electric control can be added to recording instruments as standard components.

Specialized Problems in Rocket Telemetering; *Marcus O'Day* (*Air Force Cambridge Research Laboratory*).

Space, weight, and aerodynamic limitations demand that rocket-borne research equipment (especially as it relates to the investigation of the physics of the upper atmosphere) be designed for several combined functions of communication and control. A telemetering system is needed for data recovery, and a transponder beacon, for accurate range data. Multiplexing telemetering or other signals with the beacon reply also makes more efficient use of the frequency band and reduces the number of rocket-mounted antennas. Three special devices are:

1. In the ionosphere beacon, a very long reply pulse was amplitude-modulated to carry the distorted shape and time delay of a 4-megacycle pulse which had traveled through the ionospheric *E*-layer.

2. Fifteen channels of pulse-width telemetering were inserted upon the normal vertical blanking pulse from a rocket-borne television transmitter. The signals were separated on the ground and the telemetered information displayed on a cathode-ray tube with a roster-type scan.

3. The beacon for the Air Forces' Aerobee rocket transmits a range pulse on *S*-band, a range pulse, and two telemetering pulses on *L*-band, and operates both a fail-safe and a positive command circuit to bring down the rocket in case of emergency. Telemetering signals are transmitted by varying the position in time of the telemetering pulse relative to that of the range pulse. The fail-safe circuit holds open the normally closed relay which controls the detonate circuit in the rocket, as long as the beacon is properly receiving interrogation signals. The command circuit is frequency-sensitive and closes the detonate circuit when the beacon repetition rate is shifted to the command rate.

An Electromechanical Transducer; *J. F. Engelberger, H. W. Kretsch* (*Manning, Maxwell, and Moore*).

The Electromechanical Transducer changes mechanical and certain electrical quantities into corresponding electric current, mainly for purposes of remote transmission. Operating on the principle of a continuous torque balance, the "Microsen Balance" actually is a small servomechanism which, by virtue of using an external power

supply for its operation, is also capable of raising the power level of the input signal. For electrical inputs, therefore, it becomes an electromechanical d-c amplifier.

The "Microsen Balance" consists of a balanced beam structure wherein mechanical inputs are applied through a hairspring at the fulcrum of the beam. A coil is also mounted on the beam and suspended in a pot-type permanent magnet in such a manner that current flowing in the coil produces torque opposing the torque of the hairspring. Unequal input and output torques cause the beam to deflect. This deflection is used to change the tuning on a 40-megacycle tuned-grid tuned-plate oscillator without reflecting any appreciable torque on the beam structure. The degree of oscillation changes the d-c resistance of the tube which, in turn, controls the d-c output current and also the amount of current fed back to restore balance which is always a fixed portion of the output. Electrical inputs, if used, are applied through a second coil suspended in the same magnet.

An analysis of the accuracy and frequency response is presented using Nyquist criterion and inverse-plane methods. Depending on the amount of feedback used, frequency response up to 15 cycles is obtainable.

Telemetering at Glenn L. Martin Company; *J. M. Pearce (Glenn L. Martin Company).*

Martin Electronics has developed telemetering systems for four principal missile projects: Gorgon IV (KUM-1) Ram-Jet Test Vehicle, Ground-to-Ground Guided Missile, an Air-to-Air Guided Missile, and a proposed system for a Propulsion Test Vehicle. It is to be noted that each of these missiles, being a different type, presents its own special class of problems. These developments have been concerned not only with telemetering system design but also with system construction, testing, and operational application in missile field tests.

Gorgon IV (KUM-1): The telemetering system for the Gorgon IV (KUM-1) missile secured performance data during flights of this ram-jet test vehicle. The air-borne equipment of the Gorgon IV system is a commutated frequency-modulated subcarrier type with four basic pickups: pressure, strain gauge, motion, and signal converters for control system signals. A 16-position switch is used which provides one extra contact for master synchronization. The transmitter is crystal-controlled frequency modulation with a nominal power output of 15 watts at 217.55 megacycles. The antenna, a center-fed dipole, is part of the Pitot boom on the nose of the pilotless aircraft. The system was designed to take measurements in fairly rapid time sequence by modulating a single transmitted carrier.

The instrumentation of the Gorgon IV was designed to measure: air speed, altitude, fuel flow, jet inlet pressure (Ram-Jet Engine), forward thrust of engine, motion of spoiler (actuated air guiding surface right side), motion of spoiler (left side), brake motion, acceleration (horizontal), roll of vehicle, elevator position, pitch of vehicle, altitude correction, acceleration (vertical), and elevator hinge moment.

Several of the air-borne instruments are variable-reactance type designed and manufactured in the laboratory. Other instruments are resistive and strain-gauge type.

The ground portion of the Gorgon IV Telemetering System consists of a receiver, wire recorder, demodulators, and recording oscillographs with provision for photo recording of panel data. The ground telemetering station, including all equipment for data recording and ground test of missile telemetering equipment, has been built into a trailer for mobility.

Special Transducers for Basic Parameter Electric Conversions; *C. A. Dyer (Minneapolis-Honeywell Regulator Company, Brown Instruments Division).*

This paper discussed several of the more commonly used transducers for converting physical quantities to usable electric signals. The subject was approached by a discussion of the basic potentiometric and Wheatstone-bridge-type instruments as they are commonly used in industry.

It was pointed out that modern instruments of this type which employ servomechanisms in obtaining null balance are very flexible, particularly when used in conjunction with the great variety of transducers which are now available. Particular emphasis was placed on the flexibility of the strain-gauge type of transducer which is capable of converting various types of motion as well as the conventional stress and strain effects into suitable electrical equivalents. It was pointed out that several of the conventional primary devices used for measuring high vacuum are also admirably suited for use in connection with recording instruments.

Radiosonde Telemetering; *Louvan E. Wood (Friez Instrument Division, Bendix Aviation Corporation).*

The modern radiosonde was developed to meet a need long felt by the meteorological services for a quick, reliable means of measuring the characteristics of the upper atmosphere. It represents an example of progress in meteorology following advances in communications systems.

Experiments in radiosonde telemetering started 20 to 30 years ago and various methods were experimented with for converting measurements of atmospheric temperature, pressure, and humidity to a form suitable for radio transmission. These centered around chronometric measurements, the use of commutator systems, and the control of oscillator frequencies as a measuring means.

The type of instrument in use in this and a number of other countries, is that known as the audio-modulated frequency system originally developed by Messrs. Diamond and Hinman of the National Bureau of Standards. This instrument measures atmospheric temperature, pressure, and humidity and, when using a suitable radio frequency and operated in conjunction with suitable receiving equipment, may be used to determine wind speeds and directions.

Atmospheric pressure is measured by means of a pressure switch, consisting of an aneroid cell with associated mechanism for moving a contact point over a commutator which alternately connects temperature, humidity, and reference resistors into the circuit of a relaxation oscillator which, in turn, modulates a radio-frequency oscillator. The temperature and humidity resistors are devices whose resistance is a function of the elements being measured.

Three radio frequencies are currently used in radiosonde work, 72.2 megacycles, 403 megacycles, and 1,680 megacycles, the latter two being suitable for direction finding, as well as measurement of pressure, temperature, and humidity.

High-Speed Multichannel Switching; *Dudley E. Woodbridge (The Applied Science Corporation of Princeton).*

High-speed multichannel switches are mechanical devices which sample a relatively large number of different electric input signals and pass these pulses of information through a collector ring to a single output. These devices have become increasingly important in telemetering systems since they are much more simple and smaller and weigh considerably less than equivalent electronic switches. Life compares favorably with that of vacuum tubes. Sampling rates for such switches can be as high as 60 channels "make-before-break" at 60 revolutions per second with long life.

This paper illustrates the use of sampling switches in telemetering systems, strain-gauge sampling, d-c chopping, calibration, and other applications. Diagrams were shown illustrating switches applied in commutated and subcommutated telemetering.

Accuracy Concepts in Telemetering; *H. C. Thomas, E. E. Lynch, (General Electric Company).*

Three important properties of a measurement system are accuracy, precision, and repeatability. A comprehensive understanding of these properties requires both a definition of the terms, and means for their quantitative expression.

Measurement error (or its limit), which is a commonly accepted basis for expressing quantitatively the concepts of accuracy, precision, and repeatability, can be resolved into three fundamental components, which when properly combined clearly reveal the basic significance of each of these properties, and provide the key to the comprehensive understanding of the underlying concepts.

The A component of error is the most probable error, for which a correction can be made. The B component of error is the uncertainty in the A component, which is present because of uncertainties in original calibration, changes of calibration with time, and influences due to ambient conditions at the time of measurement being different from those for which the original calibration was obtained, and so forth. The C component of error is the uncertainty resulting from limitations in the readability of the measurement systems and from uncontrolled or indeterminate variations in ambient conditions during the time of measurement. The B and C components of error are expressed as a limit of error, with a definite probability of not being exceeded.

Repeatability is the degree to which repeated measurements yield identical measured values, and is expressed in terms of the C component. Precision is the degree of reliability of a measured value and is expressed in terms of $(B+C)$. Accuracy is the degree to which a measured value conforms to the true value, and is expressed in terms of $A \pm (B+C)$.

Great Lakes District Meeting Features Transmission and Distribution Papers

The 2-day meeting of the AIEE Great Lakes District, held in Jackson, Mich., May 11–12, 1950, featured the subject, "Transmission and Distribution of Electric Energy on Systems With Low Load Density." Many of the papers which were presented in the seven technical sessions completing the program were directly related to the theme of the meeting. In addition, two sessions were held in which papers were presented in District Branch competition by the Branch Prize winners. Inspection trips were taken to nearby industries and power installations with a banquet each evening and a specially arranged program for the ladies. The total attendance of 536 members, guests, and students evidenced one of the most successful District meetings in the annals of the Institute.

GENERAL ACTIVITIES

The meeting was opened on Thursday morning by C. D. Malloch, General Chairman of the meeting and General Operations Supervisor for Consumers Power Company, who introduced such men of prominence in the Institute in attendance as E. F. Dissmeyer, Commonwealth Associates Inc., and Chairman of the Michigan Section; Professor I. B. Baccus of Michigan State College, Vice-Chairman of the Michigan Section; O. E. Bowlus, Chrysler Corporation, Secretary of Michigan Section; E. W. Seeger of Cutler-Hammer Corporation, Milwaukee, Chairman of the Great Lakes District and Vice-President of the Institute; Professor E. W. Kane of Marquette University, Milwaukee, Chairman of the District Committee on Student Activities; H. H. Henline of New York, N. Y., Secretary of the Institute; and E. Holmgren, Chairman of the Northeastern Michigan Section. Mr. Malloch then introduced J. R. North, Chief Electrical Engineer of Commonwealth Associates, who, in turn, introduced J. F. Fairman, President of the AIEE and Vice-President of Consolidated Edison Company of New York. Mr. Fairman presented an address on "Democratic Processes."

When he first started Institute work in Michigan, Mr. Fairman, in common with most mid-westerners, felt that Institute activities were controlled by a small group of people at Headquarters. He believes that the Institute membership should have a great part in the shaping of Institute policies. The present activity of trying to reorganize the general policies of the Institute grew out of that attitude. It began in President Wickenden's term by the reorganization of the technical committee structure. Mr. Fairman was appointed Chairman of a Committee on Planning and Co-ordination. The outcome of this activity was to simplify the committee organization so that whenever a particular segment of the electrical industry felt it needed more representation, a new committee could be readily formed to fill this need. Thus, the number of committees has been doubled in the last few years.

He discussed the part the engineers should take in public affairs. Again, it was felt that the electorate of the Institute should settle this problem. The result of the committee's work on this was the first public opinion poll which indicated strong support for the first proposition—that the Institute should continue as principally a technical organization. As a result of this poll, a second ballot was taken, the current one. Results so far (only 11 per cent) are very disappointing; they indicate 13 to 1 in favor of proposition 1, and 10 to 1 in favor of propositions 2 and 3.

However, the point Mr. Fairman emphasized was that he was very much disappointed in the interest the membership was showing. He drew a parallel with the way we are treating our national democratic system. He feels that the great danger in our democracy is the amount of lethargy on the part of most of us, and he ended with the plea that, in Institute affairs, as well as in national affairs, we each resolve to take more interest in these things which are of vital concern to us. Only thus can we make democracy continue to work.

At the noon luncheon on Thursday at the Hayes Hotel, A. W. Rauth, Consumers Power Company and Vice-Chairman of the meeting, presided. The toastmaster was Ralph J. Andrews of Sangamo Electric Company, who introduced Fred Wetmore, Chief Electrical Engineer of Detroit Edison Company and Professor D. D. Ewing, Head of the Electrical Engineering Department of Purdue University. N. C. Pearcy, Pioneer Service and Engineering Company, introduced Professor Kane, who spoke on student activities, and Vice-President E. W. Seeger, who discussed activities of the AIEE Great Lakes District, emphasizing the points brought out in Mr. Fairman's address.

The main banquet was held on Thursday evening at the Hotel Hayes with C. D. Malloch presiding and E. V. Sayles as toastmaster. Highlight of the occasion was an address by R. S. Peare, Vice-President of the General Electric Company in charge of Public Relations and Manager of the Advertising and Publicity Department. Mr. Peare was introduced by J. H. Foote of Commonwealth Associates, Inc.

In his talk, entitled "Facilities of Hell," Mr. Peare told how society today yearns for the complex machinery which has been developed by science during the last thousand years, but how it desires none of the complex problems attendant on this progress. "Science and engineering have become part of the structure of the house that man is going to build for himself," he said, "but the lack of a follow-through by men on their jobs to see that each task is finished has brought about the present condition." He urged America to restore its "pioneers," pointing out that the three factors—American democracy, American capitalism, and the modern American corporation—have given us room for individual contributions above and beyond earning our daily bread. Through them our science and technology have become, not the facilities of hell, but the security and hope of free men.

In conclusion, he told his audience that it is up to each of us, individually, to undertake a widespread educational program designed to implant in the minds of great numbers of people the few simple, basic principles that distinguish the way of life for which we stand from that toward which the world has been trending.

At the student luncheon on May 12, J. Strelzoff of Michigan State College acted as toastmaster. Among those that he introduced at the speaker's table was AIEE President J. F. Fairman, who directed a few words to the students concerning their activities and interests when they go out into the world in the various communities. He stressed the importance of their belonging to professional societies and taking an active part and active interest in both technical societies and in community affairs, and of being well-rounded engineers.

Dean L. G. Miller, of the engineering school of Michigan State College, presented the main address; his theme was to the effect that the tools for the student's education and the tools with which he shall work after graduation must be provided for him. To date the student has had to learn and accumulate knowledge for which investment someone else has been paying. Likewise, when he takes a job in industry, capital must invest money for a place for him to work and also to provide him with a job. He told the Biblical story on stewardship in modern terms, citing how the owner of an industry going into a far country called his three foremen together and gave them each particular phases of the work to handle.

Future AIEE Meetings

Middle Eastern District Meeting
Lord Baltimore Hotel, Baltimore, Md.
October 3–5, 1950
(*Final date for submitting papers—July 5*)

AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine
Park-Sheraton Hotel, New York, N. Y.
October 23–25, 1950

Fall General Meeting
Skirvin Hotel, Oklahoma City, Okla.
October 23–27, 1950
(*Final date for submitting papers—July 25*)

Conference on High-Frequency Measurements
Washington, D. C.
January 1951

1951 Winter General Meeting
New York, N. Y.
January 22–26, 1951
(*Final date for submitting papers—October 24*)

When he returned, the first foreman had doubled the number of items he was producing in his section, had cut the production time, and had increased the profits. Likewise, the second foreman had doubled production, items produced, and profits in his section. The third, believing in security and that the owner wanted things to remain as they were, thus had left things as they were, changing nothing, and showing no advancement. The thought to be drawn from this was that one should be a good steward and take an active interest in one's work.

STUDENT ACTIVITIES

At the student banquet which was held on Friday evening, E. W. Kane of Marquette University, Great Lakes District, Chairman in charge of student activities, presided, and E. W. Spring of Detroit Edison, Chairman of the Student Branches of the Michigan Section, acted as toastmaster. F. E. Sanford, National President of Eta Kappa Nu and Assistant Chief Electrical Engineer of Commonwealth Associates, Inc., in the featured address of the evening outlined the national employment picture for students. He said that this year the students would have to look for jobs and he suggested that small businesses and industries, in which someone conceives and then manufactures a product for years, venturing into no new fields, need engineers to help develop and improve the business. Another possibility lies in industry where older men will have to be replaced in the near future. Mr. Sanford stressed the fact that work will be available if the young engineer goes out and searches for it, proving that he is needed, and he showed that in a few years there again will be a shortage of graduates compared with jobs, and they who are best fitted will then step into the positions.

Following Mr. Sanford's address, J. Strelzoff, Michigan State College, presented awards for students' winning technical papers. The first prize for graduate students went to Robert G. Lewis, Illinois Institute of Technology, and the second prize to John Tempka, Northwestern University. First place in the undergraduate division was awarded to Russell K. Soderquist, University of Iowa; second place to John J. Wood, University of Illinois; and third place to Harry Allwine, University of Detroit. Winners of honorable mention were John R. Davies, University of Michigan; Herman Bergstedt, North Dakota Agricultural; and Darrell H. Reneker, Iowa State College.

During the Great Lakes meeting, two student sessions were held in which papers were presented by the students as follows:

Graduate Papers

"Selective Matching of Components," Vernon J. Fowler, University of Illinois
"Design of an Improved Electronic Organ," Robert G. Lewis, Illinois Institute of Technology
"Network Approximation in the Time Domain," John Tempka, Northwestern University
"Fundamentals of Antenna Radiation," Hugo Myers, Michigan State College

Undergraduate Papers

"A Synchronous Mechanical Rectifier," Robert W. Greer, Milwaukee School of Engineering
"Medical Electronics," Edward Ohm, University of Wisconsin
"Quantitative Requirements for the Reproduction of Sound," John R. Davies, University of Michigan
"A Phonograph Amplifier," Leland T. Thomasson, Purdue University
"What Does Co-operative Training Offer to the Engineering Student?" Ray Meier, Harry Hesse, Marquette University
"Electroencephalography," John F. Wood, University of Illinois
"Gaspipe Radio," Robert L. Borchardt, University of Minnesota
"A Precipitation Detector for Controlling Pavement Heating," Harry Allwine, University of Detroit
"A Qualitative Discussion of the Transistor," Darrell H. Reneker, Iowa State College
"Eddy Current Brake," Herman Bergstedt, North Dakota State College
"The Design and Analysis of a Rotating Regulator," Clyde H. Hoffman, University of North Dakota
"A-C Network Analyzer Board," Anthony Secresty, Jr., Wayne University
"A Photoelectric Function Generator," Stanley J. Goslovich, Illinois Institute of Technology
"Galloping Conductors," James Farley, Northwestern University
"An Electronic Counter Circuit for Use With an Automatic Drop Collector," Harold Whiting, Michigan State College
"A One-Half-Million-Volt Selenium Rectifier," Russell K. Soderquist, University of Iowa
"System Stability Studies," John Machinchick, Notre Dame University

TECHNICAL SESSIONS

In the seven technical sessions which were held, many of the papers and discussions supplemented the general theme of the meeting in that they brought out the latest designs and practices in the Great Lakes region. One of these was a paper on "The Goerges Phenomenon—Induction Motors With Unbalanced Rotor Impedances," by H. L. Garbarino of the General Electric Company and Eric T. B. Gross of the Illinois Institute of Technology. The Goerges phenomenon is the operation of a 3-phase wound-rotor induction motor at half of synchronous speed, and is obtained by unbalancing the rotor circuit. Results of tests and calculations for a 5-horsepower motor were compared and found to be in good agreement. In another paper, "Commutation in Universal-Type Motors," by L. C. Packer of the Westinghouse Electric Corporation, the many problems influencing satisfactory commutation such as electrical and magnetic conditions, mechanical condition of the armature, carbon brush condition, and in some applications such as portable electric tools, atmospheric conditions, were discussed. In the same session, still another paper described the application of "Motors and Control to Air Compressor Drive."

In another session on power generation, "Modern Power Supply Facilities" were outlined by J. H. Foote of Commonwealth Services, Inc. He stated that increased pressures and temperatures of steam, together with regenerative heating and temperature compounding and the continued development of auxiliaries, have raised the possible efficiency of steam-electric stations

Fall General Meeting Inspection Trip

An inspection trip to the Arthur S. Huey generating station of the Oklahoma Gas and Electric Company has been arranged in conjunction with the 1950 Fall General Meeting of the Institute to be held in Oklahoma City, October 23–27. The feature interest at this station is the first commercial installation of a gas turbine unit applied to central station electric generation in the United States. This unit has been in service since July 1949 and has been phenomenally successful both as to dependability and performance. It has attracted international attention and will be seen in actual operation

and at the same time have increased the responsibilities of designers of modern power supply facilities. Higher thermal efficiencies and higher initial costs must be balanced economically, with fuel and other costs at a particular location as the principal factors, to the end that neither minimum investment nor maximum fuel economy is a dominating goal in itself. The location of a plant in the electrical system of which it is a unit, the requirements of the load it is to serve, and the characteristics of existing facilities must all equally influence the design.

In a session on transmission, a paper entitled "Transmission Substation Design—A Departure From the Usual," was presented by E. V. Sayles of the Consumers Power Company. Mr. Sayles stated that a departure from the usual design of any part of the electrical plant is justified only if substantial gains can be realized in operation, maintenance, safety, or over-all costs. With operation, maintenance, and safety reasonably well accounted for in many excellent designs, the development of new designs admittedly must be directed toward the goal of lower investment and its components of standardized methods, simplified construction, and courage to depart from the traditional when sound judgment dictates.

INSPECTION TRIPS

During the meeting, trips were taken to engineering features of interest which exemplified the theme of the meeting. Among the places visited were the B. E. Morrow Steam Plant at Comstock, the installation of aerial cable by the spinning method, Michigan State College, the W. K. Kellogg Company, the Clark Equipment Company, and the Goodyear Tire and Rubber Company.

LADIES' ENTERTAINMENT

After getting acquainted, the ladies had a busy time during the meeting. Members of the ladies committee were available to help arrange sight-seeing, shopping, and other activities. On Thursday there was a luncheon at the Jackson Country Club, and on Friday morning, the ladies inspected the W. K. Kellogg Company in Battle Creek, Mich.

COMMITTEES

The officers of the District Meeting Committee were as follows: C. D. Malloch, *General Chairman;* A. W. Rauth, *Vice-Chairman;* F. E. Davis, *Secretary;* E. V. Sayles, J. H. Foote, J. R. North, F. G. Boyce, *Committee at Large;* E. F. Dissmeyer, I. B. Baccus, O. E. Bowlus, *Advisory Committee.*

The chairmen of the subcommittees which made the arrangements were as follows: M. W. Balfour, *Program;* B. S. Moulton, *Entertainment and Sports;* E. S. Jackson, *Publicity;* H. W. Hartzell, *Contact;* W. E. Jacobs, *Inspection;* J. S. Francis, *Registration;* L. W. Robinson, *Finance;* B. P. Carr, *Transportation;* F. Von Voightlander, *Information;* H. R. Wall, *Hotel;* Mrs. E. V. Sayles, *Ladies' Activities;* J. Strelzoff, *Student Activities.*

749 Attend Washington Symposium on Improved Quality Electronic Components

Components for military electronic equipment must be designed to serve without replacement during the normal life of the equipment if electronics is to continue in its role of increasing importance in modern welfare. This was the idea stressed during a 3-day symposium held in the Auditorium of the Department of the Interior, Washington, D. C., May 9–11, 1950.

The Symposium on Improved Quality Electronic Components was sponsored by the AIEE, Institute of Radio Engineers, and the Radio Manufacturers Association, with active participation by agencies of the United States Department of Defense and the National Bureau of Standards. The conference was attended by 749 engineers and scientists from all parts of the United States as well as representatives from Canada, Great Britain, Australia, New Zealand, and Sweden.

The meeting was opened by F. J. Given, Bell Telephone Laboratories, the chairman of the Symposium Committee, who announced that it was the first time an engineering meeting of that size had been devoted solely to electronic components. After this welcoming address, the opening session, "Dependability in Electronics," was taken over by the session chairman, A. V. Astin of the Bureau of Standards.

DEPENDABILITY IN ELECTRONICS

The first paper, "Why Not Dependable Electronics?" was presented by F. R. Lack, Western Electric Company, who gave some of the history of the development of electronics leading up to the fact that essentially electronics is still in the laboratory stage and is just acquiring the proper engineering slant. Electronic gear of today does not compare in dependability with electric motors, generators, power equipment, and so forth, which are definitely out of the laboratory. It has become habitual to overwork electronic components—operating vacuum tubes beyond their normal rating—and this is a wrong philosophy. It is essential that component manufacturers make their electronic products dependable in accordance with strict engineering principles.

L. V. Berkner, Carnegie Institute of Washington, gave the Navy's viewpoint in "The Military Dilemma Produced by Electronics." From a logistics study of the personnel necessary in the event of another war, it was found that insufficient men were available to maintain the electronic equipment. A good maintenance man needs two to four years of general training and four to ten weeks training on each new piece of electronic apparatus. This training of personnel costs 10 to 100 times the value of the equipment, not to mention the cost of the training equipment, the training bases, food, clothing, pay, and all the other factors that enter into the cost of living. These high cost figures—and they run into millions of dollars annually at the present time—demand that electronic equipment be so designed and built that it be maintenance-free and that its life be a minimum of 1,000 hours with double this time as a goal.

The next paper, "Commercial Electronic Equipment," was presented by D. E. Noble, of Motorola, Inc., who spoke for sectionalized equipment, especially in mobile sets. In trouble-shooting, testing is performed intuitively and in wartime this procedure is too time-consuming. Incorporating portions of circuits, for instance an audio-frequency amplifier, in a section or unit, testing the section as a whole, and replacing it if defective, will accelerate the entire operation. Sections would be expendable or could be salvaged at a repair base if the defects were not too extensive.

"Quality Need Not Be a Luxury in Domestic Equipment" was the subject of R. F. Rollman's paper; he is with Allen B. Dumont Laboratories. Customers for television receivers are willing to pay for quality, but competition in the field is tending to reduce prices of sets; nevertheless, quality must be retained. Nearly 1,000 components are in a modern television receiver and these are made by hundreds of different manufacturers. It follows then that component manufacturers must have a quality program and adhere to it strictly.

Such a program entails the engineering of the product so that it satisfies the consumer's demands and that it functions to its fullest capability; a constant vigilance must be kept on the product's quality and immediate steps be taken to restore the quality if it falls below a certain limit.

The fifth paper of the session, "Reliability in Air-borne Electronic Equipment," by C. R. Banks, Aeronautical Radio, Inc., considered the problems encountered at air fields by users of electronic equipment. Due to the increase in speed of aircraft and the changes in their handling because of greater traffic, it is necessary to reduce the intervals of landings from four minutes to 90 seconds. It follows that this reduced time means a greater reliance on electronic equipment, which of necessity must be reliable to an even greater extent than heretofore. Because of this factor, today it is necessary that duplicate apparatus be carried in the stock room so that continuous operation can be maintained at all times, which means a considerable investment mainly because the electronic equipment is not as reliable as it should be.

E. D. Cook of the General Electric Company took the customer's viewpoint in his paper "Industrial Electronic Equipment." In many instances maintenance on electronic equipment is practically impossible inasmuch as the equipment is operating continuously and to shut it down would entail a considerable loss. Under such circumstances, if electronic equipment is to be accepted by certain industries, its reliability must be beyond question: the components comprising it must have a longer life than they possess at the present time.

"The Need for Quality Performance in Laboratory Instruments," by P. K. McElroy, General Radio Company, was the closing paper of the morning session. Because high-accuracy instruments must have a higher accuracy than anything which they are used to measure, the components comprising them must be of even higher quality than ordinary. Some instrument manufacturers have diffi-

culty in buying components of the necessarily high quality and have been forced to design and manufacture their own parts in order to keep their product to a high standard.

DESIGN AND FABRICATION TECHNIQUES

The afternoon session on "Unitized Design and Electronic Fabrication Techniques" had as its chairman C. Brunetti of the Stanford Research Institute, who presented the opening paper, "Electronic Design Trends and Techniques." Unitization of equipment into subassemblies is necessary for optimum efficiency, especially when maintenance is considered. In the event of trouble, units can be replaced successively until the defective one is found with a minimum of time spent. It has been found that the time down of radar equipment has been reduced to a marked degree by unitizing the various electronic portions of the sets because the trouble was located more easily.

The unitizing of equipment has certain criteria which should be followed. Among these criteria are: each unit should have one electronic function, as an amplifier, detector, or tuner; the relative life of each component should be uniform; consideration should be given to its thermal capacity, the impedance at its junction points, and its compatability; it should be easily fabricated and have optimum reliability. All these points lead to the fact that a new fabrication technique is needed which will obtain universally.

The next speaker was W. S. Parsons of Centralab Division, Globe-Union, Inc., whose subject was "Printed Electronic Circuits—Applications and Aspects." In 1942 the demand was for a small, compact electronic chassis and one answer to the problem was printed circuitry. This necessitated the metallizing of ceramics and the speaker described the search his company had conducted for the best process. It has been found that printed circuits have a good stability and that their use has reduced maintenance time.

The papers read by A. Gross of Stewart Warner Electric Company, "Miniature Printed Circuit Electronic Assemblies," and R. L. Goetzenberger of Minneapolis-Honeywell Regulator Company, "Stamped and Sprayed Copper Wiring Techniques for Simple Rugged Electronics," dealt with examples of printed circuitry. Mr. Gross exhibited his company's Citizen's Set, a portable transmitter-receiver in which use is made of the printed-circuit technique, and explained how this new fabrication enabled them to reduce the number of units and the over-all size. Mr. Goetzenberger described how printed units made for ease of mass production; how their resistance to vibration and temperature change were increased; and how easily leads between units could be produced.

R. M. C. Greenidge, Bell Telephone Laboratories, in his paper "Unitized Designs in Telephone Applications," explained how the design factors in this type of communication work demanded a service life of 20 years from both electrical and mechanical viewpoints; how standardization was achieved, and how economic factors and hazards to personnel were considered.

The factor of thermal effects was discussed in the next three papers. W. H. Hannahs, Sylvania Electric Products, Inc., presented a paper, "Heat Transfer in Miniaturized Unit Assemblies," in which he described the various sources of heat in a miniaturized unit and what means were taken to dissipate it. W. G. Wing of the Sperry Gyroscope Company explained the design of hermetically sealed amplifiers and how the subassemblies of the amplifiers' components had to be designed and built in order that they be usable in tropical climates and be proof against abnormal temperature, moisture, and so forth. With such rigid requirements as these, it is essential that the individual components have the maximum dependability. "Recent Developments in Potted Circuits" read by W. G. Tuller, of Melpar, Inc., was a progress report on this type of circuit of which approximately 1,000 units have been produced in a pilot plant. A clear plastic enclosing two vacuum tubes and a transformer, with a pronged base for connecting to the external circuit proved to be a satisfactory arrangement for hermetically sealing the units. The ideal design would be to seal the assembly as a whole hermetically and not the individual components.

"A Program Towards 100 Per Cent Reliability in Telemetering Components" was the subject of a paper by W. J. Mayo-Wells of The Johns Hopkins University's Applied Physics Laboratory. He traced the history of telemetering component design, discussing in particular the channels needed and their required accuracy. The entire system has been greatly improved in the past two years to the degree that one unit after a missile trip, in the course of which the unit was dropped thousands of feet from the sky, was found to be correct to one per cent upon calibration. The speaker offered seven types of information which are available at The Johns Hopkins Laboratory to those interested in the development of telemetering units.

In the discussion which followed the afternoon session, a semiautomatic assembly system was described which was employed in the manufacture of a frequency-modulated unit for the Army. The new assembly process employed at Bendix Aviation on the Pacific Coast was described wherein resistors, capacitors, and vacuum tubes are stacked with their leads on one side and then the circuit leads are brought out to match the components' leads and all of them soldered. A great amount of interest was shown in the potting technique.

COMPONENTS

The subject of the second day's sessions was "Components" with F. J. Given presiding over the morning session and S. H. Watson, Radio Corporation of America, in charge of the afternoon session.

E. I. Green, Bell Telephone Laboratories, was the first speaker and discussed "Dependable Components." Using the equipment of the telephone system as an example, Mr. Green showed that resistors, capacitors, varistors, vacuum tubes, and so forth, caused a very small percentage of the time down and that this record was due to the fact that the components were designed for the circuits for the most part. Even though the cost of such parts was high, the expenditure was justified as these components were dependable. He stressed the importance of quality-control charts.

Giving the viewpoint of the consumer of capacitors, C. E. Applegate, Leeds and Northrup Company, told of the equipment manufacturer's requirements. Recorders must function under all conditions of temperature, humidity, or atmosphere acidity. The electrical characteristics of capacitance are the main factor, with the mechanical features of minor consideration; in general, commercial capacitors were satisfactory for instruments, but if the accuracy of the equipment was paramount, then improvement was necessary. The speaker exhibited a polystyrene capacitor, which his company had designed for instruments of higher than average accuracy.

The producer's viewpoint was next discussed by Louis Kahn, Aerovox Corporation, in "Paper and Plastic Capacitors." After pointing out the difference between the military and civilian requirements, the speaker said that the reliability of a capacitor depends on the circuit in which it is used as well as the component itself. He warned that a circuit developed in "bread-board" style was really a far cry from the finished product inasmuch as there was usually a great difference in the physical disposition of the components in a container with a consequent difference in the thermal aspects. This might well have an effect on the component's life and insulation resistance, and the capacitor manufacturer should not be blamed if such changes occur under these circumstances. Mr. Kahn said that a better understanding would result if there were an increased co-operation between the circuit designer and the manufacturer.

Another producer's viewpoint was shown in B. B. Minnium's paper on "Mica and Ceramic Capacitors" read by Ben Arsdale. It was pointed out that primarily capacitors are made for the mass market and that interruption of service is not too important a matter in a broadcast receiver or television set, but it is a different matter in military installations. As no equipment can be better than its weakest component, so no component can be better than its weakest material; therefore, a study should be made for a better dielectric for the miniaturization of capacitors. The author showed the effect of temperature on a number of factors: the working and dielectric strengths, the dielectric constant, and the capacitance per cubic inch. It was stressed that a better dielectric is needed for high-temperature operation.

"Electrolytic Capacitors for the Armed Forces" by G. V. Peck of P. R. Mallory and Company contained a brief history of this type of capacitor which showed how electrolytics had been improved since 1941, especially in regards to the anode. The latest types were described in which it was brought out that the shelf life was affected by the temperature in which they are kept—better at lower temperatures, down to −20 degrees centigrade—and that hermetically sealed units are superior. The discussion that followed was chiefly concerned with manufacturers' problems and how the JAN specifications could be met.

The remaining three papers of the morning session dealt with coils and transformers. The first of this group was a paper, "Reduction of Losses in Air-Cored Coils," by R. F. Field, General Radio Company. It was brought out that inductors are the least perfect of the three basic elements of resistance, capacitance, and inductance, and that mainly is due to the skin effect at the higher frequencies affecting the resistance

of the coils. Mr. Field discussed formulas relating to the dissipation factor and the frequency at which it is a minimum and the various losses involved.

L. Batchelder, Submarine Signal Division of the Raytheon Manufacturing Company, presented a paper, "Magnetic Components for Ultrasonic Frequencies," in which were discussed the losses in capacitors, resistors, and inductors at sonar frequencies, which lie in the lower portion of the ultrasonic group, with particular attention being paid to inductors. The types of cores were described and the reasons for and methods of shielding the coils.

"Transformer Quality Improvement" was the title of the paper of Reuben Lee, Westinghouse Electric Corporation, who described the gains made in transformer core materials, as well as the testing procedures, circuitry, and general information. Coils treated with Fosterite, which is poured into the windings and hardens, showed good characteristics for high temperatures and high humidity after a 240-hour test run. New tests are being incorporated into the Radio Manufacturers Association standards for transmitters involving voltage tests and shielding effectiveness.

The afternoon session was a continuation of the "Components" session of the morning, S. H. Watson, Radio Corporation of America, presiding. The opening paper, "Resistors and Potentiometers," was read by P. S. Darnell, Bell Telephone Laboratories, who presented the users' viewpoint. He advocated the adoption of a standard system of preferred values of resistors which would eliminate much of the confusion existing at the present. It was also urged that the following factors should be more carefully followed for design improvement: resistance value and tolerance; wattage rating; range of frequency; stability relative to time, humidity, ambient and self-heating temperatures; the space occupied and shape of resistors, and the mounting facilities in regards to equipment arrangements; and the cost. The problems relating to different types of resistors were discussed, together with their composition, film or wire-wound. The same factors also are involved in the manufacture and use of potentiometers.

The producers' viewpoints were covered in the next two papers: "Composition Resistors and Potentiometers," by Jesse Marsten, International Resistance Company, and "Wire-Wound Resistors and Potentiometers," by G. M. Stapleton, Ward Leonard Electric Company. Mr. Marsten stated that the progress made in miniaturization has almost reached a minimum in 20 years; that for a 1/2-watt resistor the power-handling capacity has increased about five times and that the price has been reduced about 65 per cent in the same period. The composition resistors do change, but too often they are called upon to perform work far beyond their ratings. It was recommended that more research be performed to improve resistors, to ascertain what happens when current flows and what happens to the current when the temperature rises or falls.

Mr. Stapleton discussed the demand by both industry and the military for more exacting specifications on wire-wound resistors. He told about the construction of these resistors and the effect of differences on operation for high- and low-temperature ranges. In the discussion which followed it was brought out that a program is in progress to develop a coating for wire-wound resistors so they will operate for a time at 200 degrees centigrade.

Figure 1. Cutaway section of helical membrane cable

E. C. Quackenbush, American Phenolic Corporation, presented "Electrical Connectors, Past and Present" in which he asked for standardization in the electronic connectors so that those of one manufacturer can be interchanged with the connectors made by someone else, such as is possible in the electrical industry. This applies to the size, shape, and rating. More than a dozen manufacturers have made AN connectors and these are interchangeable; therefore it is possible to do this and so co-operate with the Army and Navy.

"Indicating Instruments for Dependable Electronic Equipment" was the title of the paper by J. H. Miller, Weston Electrical Instrument Corporation. He brought out that meters have been improved in the last ten years and have been reduced in size. Hermetically sealed meters are not entirely necessary even under tropical conditions of operation. The minimum range of meters seems to be 100 to 200 microamperes for maximum dependability. He told about the different meters available at the present and urged that "use notes" be more carefully followed.

An unscheduled paper was presented at the end of this session; this was by R. C. Mildner, Telegraph Construction and Maintenance Company Limited of England, and was read by H. D. Short of the Canada Wire and Cable Company, Toronto, Ontario, Canada, the title being "The Helical Membrane Cable." The center conductor of this coaxial cable is maintained in position by means of a helical insulator, as illustrated in Figure 1, which is formed by cutting it from a tube of polyethylene extruded around a special tool that controls the inner dimension accurately. In its present form the outer conductor consists of a seamless aluminum tube of not less than 99.6 per cent purity, which in certain cases may be left bare in air installations or it may be provided with a corrosion-protective covering such as is used for power cables.

Three sizes of the cable have been produced: 3/8, 3/4, and $1^1/_2$ inches. The types so far developed have a characteristic impedance of 75 ohms which is close to the condition giving minimum attenuation. The dielectric constant is 1.08 and the attenuation constant very low and within six per cent of the ideal construction. The intrinsic uniformity of the insulating helix and the use of a self-supporting outer conductor results in extremely high degree of uniformity of electrical characteristics everywhere along the cable at all frequencies up to where the periphery of the insulation approaches one-half wave length. For frequency ranges between 1 and 3,000 megacycles, the power ratings vary from 7.5 to 0.13 kw for the 3/8-inch cable; from 14 to 0.20 kw for the 3/4-inch cable; and from 40 to 0.5 kw for the largest size. At low frequencies the safe power may be limited by the voltages arising on the cable. These maximum voltages may be assumed to be the same for all frequencies and for atmospheric pressure. They are 1,300 volts for the 3/8-inch cable; 2,200 volts for the 3/4-inch cable; and 4,500 volts for the $1^1/_2$-inch cable. These ratings may be increased by the use of a gas under pressure within the cable.

When the cable is bent around mandrels of different diameters, X-ray examinations indicate that the inner conductor remains in position with respect to the sheath even though the diameter of the mandrel is as low as six times that of the cable. For sharper bends than this, the danger of short-circuiting is remote, even though the helical insulator is partially flattened. Lengths of the cable can be connected by means of a special joint which is gastight and has an extremely low d-c resistance.

The third session on "Components" was devoted to vacuum tubes and W. G. Dow, University of Michigan, who was chairman, stated that this session could be considered as a continuation of the tube conference held in Philadelphia two years ago. The opening paper, "Problems of Equipment Designer in Applying Tube Standards," was presented by T. H. Schubert, Sperry Gyroscope Company. A brief history of tube specifications was given and it was brought out that the present JAN-1A specifications needed revision. At present there are six tube programs, and these do not fit in with instrument manufacturer needs, as they do not provide sufficient data for them to realize the full capabilities of the tubes.

T. B. Perkins, Radio Corporation of America, read a paper, "Present Possibilities of Improved Tube Design," in which it was stated that tube manufacturers endeavored to keep in touch with the needs of customers by means of field application engineers. Tube manufacturers are looking for new techniques to improve their products; they are handicapped by materials which have too loose tolerances and so prevent their making tubes of consistent uniformity in performance. They are also limited by test meters' accuracy in testing.

"A Progress Report on Special Red Tubes" was made by G. D. Hanchett, Radio Corporation of America, wherein was explained the "Red" line of industrial tubes produced by his company and their testing. Tubes are selected at random for a long-life test of 10,000 hours, while others are tested for 12,000 hours, this being in addition to the regular production tests. In order to check the tubes' ability to withstand shocks, they are given a vibration test wherein they are vibrated for 32 hours in each of the three planes with the filament voltage on.

R. E. Moe, Kenrad Division, General Electric Company, presented "Industrial Receiving Tubes." In this paper the reasons were given why various tests were given to tubes designed for air-borne equip-

ment use, and how the tube design had been modified in order to overcome some of the defects that showed up under strenuous testing. It was brought out in the discussion following this paper that air-borne tubes are designed to withstand impact shock tests of 500 g (g=32 feet per second squared) and some as much as 750 g's.

"Miniature and Subminiature Tubes—Design and Control Factors Governing Life and Reliability" was presented by P. T. Weeks, Raytheon Manufacturing Company. The elements of bantam, miniature, and subminiature vacuum tubes must be rugged and their spacings must be rigidly followed with small tolerances so that they will withstand shocks. It is difficult to scale down the tube's physical dimensions, and it is necessary to determine the heat dissipated and the bulb temperature under operating conditions before deciding on a final design; however, the small tubes have proved their worth as they are very rugged.

Further information on small tubes was given by A. L. Dolnick, Sylvania Electric Products Company, in "Premium Performance Subminiature Tubes." Such tubes have been designed to function up to 175 degrees centigrade at 400 megacycles and to withstand a vibration test of 15 g and a shock test of 500 g. In the event of tube failure, they are closely inspected to determine the cause. It was found by the vibration test that elements had to be anchored more firmly; frequency tests showed that oval elements with closer attention paid to spacing tolerances were needed. Most tube failures occurred within 50 hours of a test run and these were overcome by changing the elements.

In "Improved Vacuum Tubes for Severe Operating Conditions," J. Wyman, Bendix Aviation Corporation, gave the reasons why his company had started to produce vacuum tubes of their own design. It is their aim to develop a tube with a 10,000-hour life with good ruggedness because they have reduced vibration troubles by using more suspension points with more welds.

N. H. Taylor, Servomechanisms Laboratory, Massachusetts Institute of Technology, in "Component Failure Analysis in Computers," explained "marginal checking," which is for the locating of tubes and crystals before they fail. It was found that after 10,000 hours approximately 65 per cent of the tubes were satisfactory and after 13,000 hours, tube failures could be classified as follows: 71 per cent were due to changes in characteristics; 20 per cent due to mechanical defects; 4 per cent due to gas within the tube envelope and the same percentage due to the heater burning out; and 1 per cent because of physical damage.

At the conclusion of the papers, a panel discussion and open forum was conducted with Ernst Weber, Polytechnic Institute of Brooklyn, N. Y., as moderator. The panel members were: H. Bernstein, Armed Services Electro Standards Agency; R. J. Biele, General Electric Company; M. R. Briggs, Westinghouse Electric Corporation; W. R. Clark, Leeds and Northrup Company; R. J. Framme, Air Materiel Command; R. A. Lamm, National Bureau of Standards; L. Podolsky, Sprague Electric Company; E. R. Priore, Office of Naval Research; and A. W. Rogers, Squier Signal Laboratory.

REPORT AVAILABLE

A complete report of the conference, including papers and discussions, has been prepared and may be obtained for $2.50 from AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Progress in Telemetering Is Subject of 3-Day Conference in Philadelphia

The progress that telemetering has made since the war's end and what can be expected from it in the near future was brought out during the 3-day Conference on Telemetering held at the Benjamin Franklin Hotel in Philadelphia, Pa., May 24–26, 1950.

This conference was sponsored by the AIEE and the National Telemetering Forum, which was formed in May 1948 at The Johns Hopkins University. In conjunction with the conference, eight exhibitors demonstrated their telemetering products in the display room of the Philadelphia Electric Company. The attendance was 205 with registrations from all parts of the United States and Canada. Two inspection trips were arranged to the Franklin Institute and the Raymond Rosen Laboratories.

W. F. Henn, the Chairman of the AIEE Philadelphia Section, opened the conference with a welcoming address. G. M. Thynell, the Bristol Company, was chairman of the opening session and outlined the scope of the program. "Historical Notes on Point-to-Point Telemetering" was presented by P. A. Borden, the Bristol Company. (For abstracts of this and other papers, see pages 641–43)

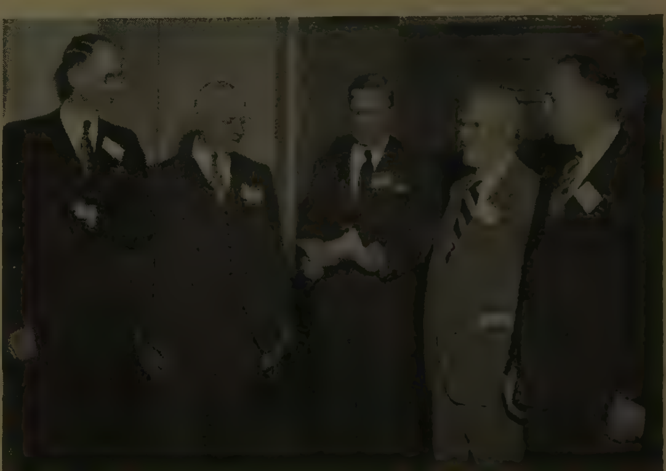
W. J. Mayo-Wells, Applied Physics Laboratory of The Johns Hopkins University presented "Historical Sketch of Mobile Telemetering." The first radio link used in telemetering was in 1928 by French meteorologists. Balloons carried a small 3-channel equipment which transmitted temperature, humidity, and atmospheric pressure to ground observers. Immediately before and during World War II telemetering was developed from a relatively simple 1-way system to the 2-way multichannel one of the present. The chief characteristics of the frequency-modulated system which are varied are the subcarrier bands, the response, commutation rates, and the type of radio link, audio modulation or frequency modulation. (See abstract, as noted in the foregoing.)

"Radio Telemetering Methods and Terminology" was read by J. F. Brinster, Applied Science Corporation of Princeton. This paper amplified the previous explanation of the several methods of telemetering and showed how the terminology of wired telemetering differed from that of radio telemetering.

H. C. Thomas and E. E. Lynch, General Electric Company, presented "Accuracy Concepts in Telemetering," which was read by Mr. Thomas. Accuracy is the degree of correctness with which a measured value agrees with the true value; precision is the degree of reliability of a measurement; and repeatability is the degree to which repeated measurements yield measured values. These terms were explained in detail and their use demonstrated in various ways. "The Functional Classification of Telemetering Systems" was given by W. H. Burnham, General Electric Company. A telemetering system can be broken down into three portions: the primary detector, the intermediate means, and the end device. The first of these is the means whereby some measurable quantity, as pressure, temperature, voltage, velocity, and so forth, is converted into a form which can be used to actuate the telemetering transmitter, the first of the components in the intermediate means, the rest of which consists of the telemetering channel, wire, radio, or some other medium, and the telemetering receiver. The end device is the means by which the intelligence is indicated, such as a cathode-ray oscilloscope, a recording meter, or a teletypewriter. By establishing the types of these three classifications a telemetering system can be analyzed.

TELEMETERING SYSTEMS

Both sessions of the second day were devoted to telemetering systems; the morning session was directed by C. H. Hoeppner, Raytheon Manufacturing Company, and P. A. Borden, The Bristol Company, was chairman of the afternoon session. The first speaker was W. E. Rufleth, Bristol



Shown at the recent Telemetering Conference are, left to right: C. K. Duff, Hydro-Electric Power Commission of Ontario; A. E. Knowlton, "Electrical World"; W. E. Phillips, Leeds and Northrup Company; P. A. Borden, The Bristol Company; S. E. Moore, Philadelphia Electric Company

Company, whose subject was "Telemetering in the Natural Gas Industry." Telemetering supplies information from the pressure stations to a central control station and the connecting link may be microwave transmission as well as multiplexed telephone, or carrier current. The control of the gas pressure can be made fully automatic by cascade control; this eliminates pressure variations and is economical. Totalizing was explained and how it provided a value of over-all gas flow. In the discussion which followed, it was brought out that the gas line itself had been tried as a carrier for high-frequency radio telemetering, but further work was necessary as the attenuation was high.

K. M. Uglow, Rocket Sonde Research Branch, Naval Research Laboratory, presented "Telemetering at the Naval Research Laboratories." A guided-missile project was started in 1944 in which was used a 10-channel pulse-interval telemetering system on 500 megacycles. Later this was increased to a 23-channel system on 1,000 megacycles and then seven more channels were added, using a sampling rate of 312$^1/_2$ per second. Continuous in-flight calibration every ten seconds is now employed.

"Telemetering in a Large Interconnected Power System" was read by C. K. Duff, Hydro-Electric Power Commission, Canada. After describing the commercial equipment having a 1-per cent accuracy used in the telemetering system in the plants in the Toronto area, he explained the problems involved in their interconnected power system wherein two frequencies, 25 and 60 cycles, are employed. (See abstract, as noted.)

J. W. Hamblen, The Johns Hopkins University, presented "APL FM/FM System," a 61-channel telemetering equipment wherein a subcarrier oscillator is modulated by a pickup device and the output frequency modulates a main carrier after passing through a level-adjusting circuit. (See abstract, as noted.)

In "A High-Speed System of Telemetering With Automatic Calibration," W. E. Phillips, Leeds and Northrup Company, presented the characteristics which such a system for use in power work should possess; then he described the instruments, circuits, and other features of an installation in use. M. V. Kiebert, Raymond Rosen Engineering Products, closed the session with "Aeronautical Telemetering." The gathering of engineering flight data has progressed from pilots taking readings while flying the airplanes through photographic records of cockpit instruments, which methods were unsatisfactory as records would be lost if anything happened to the airplane. The next step was the transmission of the images of the dials to the ground by television and then a system of telemetering was developed that transmitted to the ground all the necessary data. The author described several mobile telemetering systems and a telemetering flight control installation.

The afternoon session was opened by F. F. Uehling, Consulting Engineer, who presented "Applications of Rectified Current to Telemetering on a 2-Conductor Circuit." (See abstract, as noted.) A. J. Hornfeck, Bailey Meter Company, read "Telemetering Computing Systems for Industrial Process Functions." The automatic null-balanced recorder is well suited to short-distance telemetering systems. The elementary null system consists of a primary measuring device at the transmitter which works into a motor follow-up and meter which are shunted by an electronic amplifier and motor control. The output of this combination goes to an indicating meter and an electric or pneumatic controller. (See abstract, as noted.)

Another telemetering system suited for short distances was discussed by J. F. Engelberger who presented the paper "An Electromechanical Transducer" written in conjunction with H. W. Kretsch, both being with Manning, Maxwell, and Moore. This circuit is essentially a torque-balanced system which balances mechanical motion and current and has a great many applications. (See abstract, as noted.)

"Specialized Problems in Rocket Telemetering" by Dr. Marcus O'Day, Air Materiel Command, was read for the author. Besides the 15-channel telemetering equipment installed in a rocket, a radio beacon and radar apparatus are included which function as a transponder, these being used for ranging in measuring the *E* layer in the ionosphere and are triggered from the gun-laying radar ground installation. As a television transmitter was part of the rocket's equipment, the telemetering signals were sent out on the television carrier during the blanking periods and were separated and shown on an oscilloscope display. (See abstract, as noted.)

An extra paper was included in the afternoon program: "A Multichannel PAM/FM Radio Telemetering System" by J. P. Chisholm, Bell Aircraft Corporation, and E. F. Buckley and G. W. Farnell, Massachusetts Institute of Technology, and read by the latter. This type of telemetering system is used for guided missiles, rockets, and pilotless aircraft. It consists of 16 channels in two groups of eight each, and selection of the intelligence on each channel is made by an electronic commutator and transmitted on a frequency of 220 megacycles. The ground receiver has a demodulator for each channel and a separate recorder for each.

The paper of J. M. Pearce, Glenn L. Martin Company, entitled "Telemetering at Glenn L. Martin," was illustrated by a recently declassified motion picture showing the field testing and flight of a United States Naval air missile of the Gorgon IV type. (See abstract, as noted.)

The fourth session, of which W. D. Tietjen, Sperry Gyroscope Company, was chairman, dealt with telemetering systems and pickups. The first paper, "Special Transducers for Basic Parameter Electric Conversions," was given by C. A. Dyer, Minneapolis-Honeywell Regulator Company. (See abstract, as noted.) This was followed by "Radiosonde Telemetering" by L. E. Wood, Friez Division, Bendix Aviation Corporation, who explained the telemetering systems used with meteorological balloons which ascend to altitudes of 50,000 to 100,000 feet. (See abstract, as noted.)

G. E. White, Statham Laboratories, Inc., presented "Unbonded Strain Gauge Telemetering Pickups" in which it was brought out that strain-gauge dynamometers can be used to measure force, displacement, and other factors; different types of transducers were described which are used in telemetering. "Temperature Pickups and Their Use With Magnetic Amplifiers" was read by V. C. Westcott, Trans-Sonics, Inc. This type of amplifier is suitable with strain gauges as their output is direct current. The magnetic amplifier is employed as it can be sealed, needs no warm-up period, can be stabilized as to gain within ±1/2 per cent, and it can amplify very small voltages. While thermocouples are frequently used with magnetic amplifiers, the resistance thermometer is less troublesome.

"Solar Pickup" was read by L. M. Biberman, Naval Ordnance Testing Station. He described the use of a spinning pin-hole camera in determining the location of a body, such as a missile, using the sun as a reference, and a further development of this method into a lens and photoelectric cell arrangement in conjunction with a relaxation oscillator. By the use of a helical antenna in the head of the missile, radio signals were sent to a ground receiving station where they were recorded on a chart.

DATA PRESENTATION

The final session of the conference was devoted to "Data Presentation and Other Topics" with A. J. Hornfeck, Bailey Meter Company, in the chair. "The Metrotype System of Digital Recording and Telemetering" was read by G. E. Foster, Metrotype Corporation. (See *Electrical Engineering*, May 1950, pages 427–30.) This paper was followed by A. Hall, Massachusetts Institute of Technology, "Data Reduction and Automatic Telemetering." This paper described a system wherein the telemetering signals were presented on an intensity-modulated cathode-ray oscilloscope and photographed on a continuous 35-millimeter film. The film, on which 65 readings per inch can be recorded, is run through a decoder and then through an automatic typewriter. The decoding is done by a series of photoelectric cells and flip-flop circuits, which can select every second, third, or fourth recording as desired.

"A Semiautomatic Method of Reducing Telemetered Oscillogram Data" was read by H. B. Dickinson for J. Weaver, Telecomputing Corporation. The equipment is in four portions: a Telereader or Telecorder interprets the record; digital recording is performed by an International Business Machine (IBM) punch machine; the calculation of the data is done by an IBM calculating machine; and the results are presented by an IBM tabulation machine or Teleplotter. This was followed by a paper, "High-Speed Multichannel Switching," by D. E. Woodbridge, Applied Science Corporation of Princeton. The sampling switches are as reliable as the vacuum tubes in their circuits. They are connected to a collector which carries a composite of all the signals and these switches are classified according to their speed of operation which varies from about one inch to more than 60 inches per second. (See abstract, as noted.)

"The Present Status of Data Reduction Requirements" was presented by B. S. Benson, and M. J. Stolaroff described the performance results of the Ampex Magnetic Tape Recorder for the recording of frequency-modulated and pulse-width telemetering data.

The Conference Report to be published in the near future will contain the full papers and any discussions pertaining to them. This report may be ordered by sending \$3.50 to AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Engineers Informed of International Situation and National Defense Problems

An important informative meeting on the current international situation and the problems of national defense, which was arranged for Engineers Joint Council by Colonel E. B. LeBailly, Chief, National Organizations Branch, Office of Public Information, Office of Secretary of Defense, was held in the Pentagon, Washington, D. C., May 11, 1950. The meeting served well to show the close co-operation and co-ordination attained in the Department of Defense through the program of "Unification" with the attendant advantages of the increased effectiveness of the Armed Forces brought about through economy and the avoidance of duplication. The meeting also served to illustrate the close co-operation between the Department of Defense and the engineering societies. Among the 84 representatives who attended were many of the top engineers in the five broad fields of the profession: civil, mining and metallurgical, mechanical, electrical, and chemical engineering. Lieutenant Commander Clarence Cisin presided and gave valuable background information about each speaker.

The organization and functions of the National Organizations Branch were outlined by Colonel LeBailly. Problems and ideas can be channeled through the National Organizations Branch to the proper people in the Department of Defense. In conclusion, Colonel LeBailly expressed hope for a continuous liaison with the engineering groups throughout the country.

An address of welcome was given by The Honorable Paul H. Griffith, Assistant Secretary of Defense. He commented on the American way of life and what is being done to protect that way of life. The Secretaries have the advice of the Joint Chiefs-of-Staff. The speaker explained that unification, which has eliminated duplication of effort and reduced costs, is working in spite of reports to the contrary. He declared that industrial mobilization is moving steadily forward and comments were made on the improvement in instruments and implements of war which were beyond belief. Greeting and best wishes on behalf of the Secretary of Defense, who could not be present, were extended.

Plans and problems of foreign policy, country by country in various parts of the world, were reviewed by Paul H. Nitze, Director, Policy Planning Staff, State Department. Mr. Nitze spoke intimately and answered questions at the conclusion of his address.

Problems on progress in the application of the military aid program were explained by Major General Lyman Lemnitzer, Director, Office of Military Assistance OSD, who had had extensive combat experience during the past war.

The program of unification and its attendant advantages was outlined by Felix Larkin, General Counsel for the Department of Defense. By means of a chart on the organization for national security, Mr. Larkin illustrated the functions of the National Security Council of which the President is Chairman, the National Security Resources Board, and the Munitions Board as provided under the National Security Act. The National Security Council is a joint body of the State Department and the Department of Defense. The National Security Resources Board mobilizes manpower, products, and so forth. The Munitions Board takes care of the military requirements for all three services which is scrutinized by the National Security Resources Board which looks after the civilian needs in case requisitions exceed the supply. As a result of the unification program, the Army, Navy, and Air Force as a team sponsor a bill and organize the debate. The teamwork has resulted in a much more efficient and profitable enterprise with a speeding up of the action. The Munitions Board assigns to one service the buying for all three services, which results in a co-ordinated program not working at cross purposes. For example, prior to unification, there were some 17 different catalogue systems listing some 5,300,000 items which have been reduced to a single catalogue system with only 2,500,000 items. On the economic side, through the reduction of overhead and by better management, considerable money has been saved which according to best estimates is of the order of $1,500,000,000 a year. The saving is put into additional combat units and muscle. It makes the present 48 Group Air Force equivalent to a $52^1/_2$ Group Air Force and permits the Navy to operate and maintain seven heavy carriers, instead of six, and the Army to maintain 44,000 additional troops.

After reviewing strategic areas on the map, Brigadier General Delmar T. Spivey, Chief, War Plans Division, Directorate of Plans and Operations, reviewed the plans and progress for the air defense of the United States. He explained the importance of the civilian air defense program in the plotting and tracking of aircraft as reported to central control stations, the value of which has been proved from experience.

The objectives of the research and development program were outlined by Dr. S. D. Cornell, Director, Planning Division, Research and Development Board, who discussed the organization of several panels consisting of expert part-time civilian groups in many areas. By way of illustration, he cited six military problems, the solutions of which would be invaluable to the Armed Forces. It was his opinion that these problems would be solved by civilians, and while not the only problems, they served to illustrate that the more outside people who can be properly trained to think along such lines, the better. The invention for the detection of land mines, which proved so important in Africa and Sicily and in the defeat of Rommel, was discovered by a citizen. New ideas should be directed to The National Inventors Council, Department of Commerce, Washington, D. C.

The problem of modernization and the Navy's postwar shipbuilding and conversion program was described by Rear Admiral Frederick E. Haeberle, Assistant Chief, Bureau of Ships, Department of the Navy. Admiral Haeberle outlined the requirements for the different classes of vessels and described the construction problems of several classes of special class vessels. He referred to design trends and the ever-increasing space factor for electronic equipment. In discussion, the problem of increased maintenance of electronic equipment was raised by industry.

At the conclusion of the meeting, Alex D. Bailey, Vice-President of the Commonwealth Edison Company, expressed appreciation for the program and the opportunity to attend the meeting. He pointed out that those in attendance represented not only themselves, but the entire engineering body of the five organizations in Engineers Joint Council, a group of approximately 125,000 engineers.

United States Army Photograph

Representatives of the five engineering organizations who attended the Engineers Joint Council Meeting in the Pentagon, arranged by the National Organizations Branch of the Department of Defense

Application of Electricity to Textile Field Discussed at Meeting in Georgia

Application of electric power and equipment to the problems of the textile industry were presented at the Textile Conference, sponsored jointly by the AIEE, the School of Electrical Engineering of the Georgia Institute of Technology, and the French Textile School, which was held in Atlanta, Ga., on April 13 and 14, 1950. The meetings, which were held at the Georgia Institute of Technology, were attended by 210 engineers, manufacturers, and textile designers.

C. L. Emerson, vice-president of the Georgia Institute of Technology, expressed the official welcome to the conference; he emphasized the importance of electrical engineering in the development and advancement of the textile industry.

The papers presented during the technical program were representative of ideas in textile companies and the manufacturing concerns who make machines used in the textile industry. Digests of some of the papers follow.

PAPERS PRESENTED

The first paper presented was "The Use and Misuse of Electric Equipment in Cotton Mills," by Swaffield Cowan of the Factory Insurance Association. Fire losses in mills have been increasing for many years, paralleling the increased use of electric equipment. Causes for these fires include use of motors not enclosed in lintproof cases; installation of spark-producing equipment without the proper enclosures; improper use of lightning-protective devices and circuit breakers; inadequate grounding; mechanical abuse of the equipment; and inadequate electrical maintenance.

In the paper "Packaged Drives for the Textile Industry," W. H. Behnke of the Reliance Electric and Engineering Company, described a single-package drive unit in which is mounted the conversion unit and the a-c and d-c controls, completely factory-assembled and wired. These are available in ratings from 1 to 200 horsepower.

"Forty Years of Textile Lighting" were described by Frank E. Keener, retired lighting specialist of the General Electric Company. He read a newspaper description of one of the early electric illumination installations in a textile mill and contrasted this installation with various illuminating schemes which have been used since.

A device for applying uniform tension to yarns without harming them was described in the paper, "The Hysteresis Yarn-Tension Device," by R. J. Demartini and W. L. Butler, both of the General Electric Company. The tension control, to be satisfactory, had to maintain a constant tension for speeds up to 700 yards per minute in spite of changes in temperature and humidity, and in spite of lint, sizing, or other contaminants, and without damaging the yarn by abrasion or flexing. It had to handle changes in the diameter of the yarn without having it affect the tension, and it could not lose the yarn in passing these thick spots or in starting or stopping. Normal speed variations could not affect the tension, and the tension of the device for a particular setting had to be accurate within ± one gram. Static electricity could not be generated, and the device had to be sturdy and easy to thread.

The hysteresis yarn-tension device consists of a mounting stud, the pulley over which the yarn passes and in which a hysteresis ring and a ball bearing are assembled, a tension-adjusting cylinder containing the energizing magnets, and a cap carrying an index mark to which numbers on the adjusting cylinder are referred. The pulley is constructed of two pieces of durable plastic and grips the yarn between interleaved spokes of the two parts of the pulley. The pulley rotates with the yarn so there is no abrasion. The hysteresis ring in the pulley is in the magnetic field of the energizing magnet, and this field exerts a torque on the ring as it moves through the magnetic flux. The amount of torque exerted on the ring is governed by the air gap between the magnet and the ring.

J. G. Stepheson, Westinghouse Electric Corporation, presented the paper "Slasher Drives Up-to-Date." In this paper features of the three types of slasher drives, mechanical, combination mechanical-electric, and electric, were presented. The mechanical drive, which is the oldest type, has a fixed value of creeping speed which cannot be changed except by mechanical ratio changes, and the production speed range is dependent on cone pulleys. Abrupt accelerating is apt to cause excess wear on belting and yarn, and constant tension is difficult to maintain. The combination drive has many of the faults of the mechanical drive, but acceleration is smoother, a wider speed range is possible, and the creep speed is adjustable. Electric drives have automatically controlled tension devices; acceleration and deceleration are at predetermined rates and are easy on the yarn. The friction clutch is eliminated.

The description of "A Completely Air-Conditioned Mill" was given in a paper by H. S. Colbath of the Bibb Manufacturing Company. The installation of equipment to maintain and control temperature and humidity in an entire cotton mill, under a roof of 140,000 square feet, was covered.

The advantages of "Standardization of Range Drives for Textile Finishing" to mills, machinery manufacturers, and electrical manufacturers were enumerated by R. R. Lang of the General Electrical Company.

COMMITTEE

The committee that arranged for the technical program of the conference was as follows: Harry Uhl, *Chairman*, H. A. Dictert, M. A. Honnell, R. S. Howell, E. S. Lammers. The Atlanta arrangements for the conference were made by C. H. Taylor.

AIEE Board of Directors Holds Regular Meeting in Providence

The regular meeting of the AIEE Board of Directors was held at the Sheraton-Biltmore Hotel, Providence, R. I., on Thursday, April 27, 1950, during the AIEE North Eastern District Meeting.

The minutes of the Board of Directors' meeting held February 2–3, 1950, were approved with a correction indicating the presence of Vice-President Seeger at the session on February 3.

The following actions of the Executive Committee on membership applications, upon recommendation of the Board of Examiners, were reported and confirmed: As of February 24, 1950—5 applicants transferred to grade of Fellow and 27 transferred to grade of Member, 25 applicants elected to grade of Member and 185 elected to grade of Associate, 344 Student members enrolled; as of March 23, 1950—1 applicant transferred and 1 applicant elected to the grade of Fellow, 37 applicants transferred and 22 elected to grade of Member, 158 applicants elected to grade of Associate, 785 Student members enrolled.

Recommendations adopted by the Board of Examiners at meetings on February 16, March 16, and April 20, 1950, were reported and approved. Upon recommendation of the Board of Examiners, the following actions were taken: 18 applicants were transferred to the grade of Fellow; 97 applicants were transferred and 29 were elected to the grade of Member; 3,491 applicants were elected to the grade of Associate; 849 Student members were enrolled. Of the Associates elected, 3,348 were former Student members.

Monthly expenditures were reported by the Finance Committee and approved by the Board of Directors, as follows: February 1950, $67,165.77; March 1950, $63,055.21; and April 1950, $56,793.91.

The Finance Committee reported on its study of the adequacy of the rate of payment of the regularly authorized travel expenses. Upon recommendation of the committee, based on its findings that the present rate of 11 cents per mile one way is inadequate for short trips and somewhat excessive for long trips, the Directors voted to change the formula to 13 cents per mile one way for 800 miles or less and 10 cents per mile one way for the remaining distance of a trip.

The regularly authorized travel allowance for attendance at District Conferences on Student Activities was extended to include alternates for Branch Counselors, upon approval by the Vice-President in the District.

Upon request by members in Decatur, Ill., agreement by the Section officers concerned, and recommendation of the Vice-President of the District and the Sections Committee, the Board of Directors authorized the transfer of Macon and Christian Counties in Illinois from the Urbana Section to the Illinois Valley Section.

Announcement was made of the authorization granted by the Board of Directors by letter ballot for the establishment of an Oak Ridge Section of the Institute, as requested by members of the former Oak Ridge Sub-

section of the East Tennessee Section and recommended by the Sections Committee, with territory consisting of Anderson and Roane Counties in Tennessee, transferred from the East Tennessee Section.

The Directors voted that the transfer of the Province of British Columbia, Canada, from the territory of District 10 to that of District 9, previously authorized by the Board, will be effective August 1, 1950.

The following statement of interpretation of Benjamin G. Lamme's words "electrical apparatus or machinery," recommended by the Lamme Medal Committee, was approved for incorporation in the bylaws of that committee:

The committee in making the award shall carefully observe the limitation imposed by Mr. Lamme, that the recipient must have "shown meritorious achievement in the development of electrical apparatus and machinery." This shall be taken to mean that the meritorious achievement must be of such character that it has resulted or will result in the production of substantially improved electric apparatus or machinery. Any work which meets this requirement is admissible whether it be: in development of the theory involved; in development of the characteristics of the materials employed; in development of over-all design; or in development in other ways which results in substantial improvement in electric apparatus or machinery. The words "electrical apparatus or machinery" shall be taken to indicate discrete and self-contained devices which may or may not include mechanical moving parts without limitation as to the field of application. They shall not be taken to include transmission or distribution systems as a whole, but rather to include the apparatus and machinery that is used in making up such systems.

The Directors approved the following members for appointment by the President to the Committee of Tellers to canvass, count, and report on the ballots cast in the 1950 election of Institute officers: James M. Walsh, *Chairman*, Howard K. Amchin, D. L. Bromley, J. F. Donahue, A. A. Milusich, Robert H. Van Horn, and H. E. Weppler.

Frank V. Smith was reappointed a representative of the Institute on the Washington Award Commission for the 2-year term beginning June 1, 1950.

Report was made of the reappointment by the Committee on Electronics, by authority of the Board of Directors, of W. G. Dow as the AIEE representative on the Board of Directors of the National Electronics Conference for the year 1950.

Announcement was made of the appointment by the President, pursuant to actions of the Board of Directors, of William C. Lancaster as the representative of the Institute on the Board of Governors of the Building Officials Foundation, and of H. C. Wightman, of Rawalpindi, Punjab, Pakistan, as Local Honorary Secretary of AIEE for Pakistan; also the nomination by the President of A. H. Kehoe as the representative of the Institute on the National Engineering Advisory Committee.

The Board approved in principle action taken and recommendations agreed upon at the second Inter-Society Conference on Engineering Student Chapters, and referred the matter to the AIEE representatives on Engineers Joint Council for implementation through that agency.

After discussion of the increasing number of duties of the President, the Directors voted "that it is the sense of the Board of Directors that the President should not be expected to visit Sections or Branches; that those official visits should be made the responsibility of the Vice-Presidents, with the co-operation of Directors, or District Secretaries, or other Institute personnel who may be designated by the Vice-Presidents; and that the President concentrate his attention on general and District meetings, technical conferences, and such other meetings as should, in his discretion, be attended; also, that this action be transmitted to all Sections, and that the Finance Committee be requested to make provisions in the 1950–51 budget for such visits."

Upon recommendation of the Committee on Planning and Co-ordination, the Board of Directors approved the scheduling of the following meetings, some previously authorized but with revised dates:

1951: Southern District Meeting, Miami, Fla., April 11–13
Great Lakes District Meeting, Madison, Wis., May 24–25
Pacific General Meeting, Portland, Oreg., week of August 20

1952: South West District Meeting, St. Louis, Mo., spring
Pacific General Meeting, Phoenix, Ariz., August
Fall General Meeting, Chicago, Ill., late September or early October, including participation in the ASCE Centennial Celebration.
Middle Eastern District Meeting, Toledo, Ohio, during week of October 26.

1953: Winter General Meeting, New York, N. Y., January 19–23
Summer General Meeting, Atlantic City, N. J., June 28–July 3

The Board of Directors approved in principle a recommendation of the Committee on Planning and Co-ordination for the elimination from the Bylaws of all provisions for ex-officio committee memberships, and instructed the Committee on Constitution and Bylaws to implement this action. It was understood that all such members as are required for the proper functioning of committees may be appointed by the President, upon recommendation.

Upon recommendation of the Committee on Planning and Co-ordination, the Board authorized the consolidation of the Committee on Aural Broadcasting Systems and the Committee on Television Broadcasting Systems into one committee, "Committee on Television and Aural Broadcasting Systems."

Mr. LeClair gave a progress report of the discussions by the Exploratory Group (under the auspices of the Engineers Joint Council) which is studying the subject of increased unity in the engineering profession.

W. J. Barrett and J. L. Callahan were appointed alternates of AIEE on Engineers Joint Council.

A report was presented of the special joint AIEE–IRE committee which was appointed to explore the desirability of a standing joint committee of the Boards of Directors of the two societies to consider and report to the Boards matters of common interest. Upon recommendation of the special committee, the Directors approved the organization of such joint committee, to be known as the "Joint AIEE–IRE Co-ordination Committee," and to be composed of two members appointed by the Board of Directors of each society from the membership of the Board of Directors, for terms of two years ending January 31—in the initial appointments, the term of one member to terminate January 31, 1951, and the other January 31, 1952. AIEE representatives on this joint committee were appointed, as follows: John L. Callahan (to January 31, 1951) and Everett S. Lee (January 31, 1952).

In response to inquiries from the United Engineering Trustees, Inc., resulting from a study of the condition and facilities of the Engineering Societies Building and the building needs of the Founder Societies, the Board voted "that it is the sense of this Board that in UET's consideration of a new building, the location need not be limited to the Grand Central area in New York City, or to New York City," and voted "that this Board would favor the sale of the present building if an offer considered advantageous by UET presents itself, provided immediate exodus is not necessary, and contingent upon some reasonable expectation of finding another place."

The following locations and dates of Board of Directors' meetings were decided upon: June 15, 1950, in Pasadena, Calif.; August 4, 1950, New York, N. Y.; October 26, 1950, Oklahoma City, during the Fall General Meeting.

The Directors expressed interest, in response to a communication from the American Standards Association, in a proposed meeting in the United States in 1952 of the International Organization for Standardization, and a willingness to contribute an amount not to exceed $500 toward certain expenses in connection therewith.

Other matters were discussed.

Present at the meeting were the following:

President—J. F. Fairman, New York, N. Y.

Past President—Everett S. Lee, Schenectady, N. Y.

Vice-Presidents—J. L. Callahan, New York, N. Y.; W. C. DuVall, Boulder, Colo.; R. A. Hopkins, Los Angeles, Calif.; G. N. Pingree, Dallas, Tex.; E. W. Seeger, Milwaukee, Wis.; W. J. Seeley, Durham, N. C.; Victor Siegfried, Worcester, Mass.; C. G. Veinott, Lima, Ohio

Directors—W. J. Barrett, Newark, N. J.; E. W. Davis, Cambridge, Mass.; W. L. Everitt, Urbana, Ill.; C. W. Fick, Cleveland, Ohio; R. T. Henry, Buffalo, N. Y.; M. D. Hooven, Newark, N. J.; F. O. McMillan, Corvallis, Oreg.; A. C. Monteith, Pittsburgh, Pa.; Elgin B. Robertson, Dallas, Tex.; E. P. Yerkes, Philadelphia, Pa.

Treasurer—W. I. Slichter, New York, N. Y.

Secretary—H. H. Henline, New York, N. Y.

By invitation, in the afternoon, T. G. LeClair, AIEE representative on the Exploratory Group to Discuss Increased Unity in the Engineering Profession.

Middle Eastern District Holds Branch Prize Paper Contest

With Lafayette College as host, the AIEE Middle Eastern District (2) held its District Branch Prize Paper Competition for 1950 at Easton, Pa., April 28–29. Seventeen District 2 Branch Prize Paper winners participated.

Activities began with a luncheon on Friday, followed by the first session during which nine papers were presented. A dinner that evening for the contestants, Counselors, judges, faculty, and students featured talks by President R. C. Hutchison of Lafayette College, Professor Morland King, Dean of the School of Engineering, and Vice-President Veinott; and the presentation of $10 checks and Certificates of Award to each Branch winner by District Secretary Dynes.

The remaining papers were presented at

Pittsburgh Section Receives Growth Award

On May 15, 1950, the AIEE Pittsburgh Section was presented with the newly created Growth Award for District 2 by C. G. Veinott, Vice-President of the District. The award represents improvement for the year ending July 31, 1949, over the preceding year in membership and attendance at meetings. Shown here are Mr. Veinott (right) presenting the award to F. H. Schlough, Pittsburgh Section Chairman. Others (left to right) are: L. W. Tarn, Membership Committee; G. B. Miller, Jr., Power Generation Committee Chairman; R. J. Salsbury, Engineers Society of Western Pennsylvania representative; T. W. Alexander, Transfers Committee Chairman; L. N. Grier, Secretary-Treasurer; F. R. Benedict, Director; S. Rosenbach, Director; A. A. Johnson, Technical Program Committee Chairman; G. H. Phillips, Industrial Power Applications Committee Chairman; L. J. Berberich, Basic Sciences Committee Chairman

a session on Saturday morning and the prizes were awarded in the afternoon. First prize winner was Philip R. Herrick, Case Institute of Technology, for his paper, "The Cardiosynchronizer," which described a novel application of the electrical art to heart examinations. Runner-up was William E. Shaw of Pennsylvania State College who presented a paper on "Transistors." The Lafayette College Branch had also provided a $5 prize for each session for the best question asked in discussion. Mr. Dynes judged the questions and made awards to H. R. Stillwell, University of Pittsburgh, for the Friday session, and to W. F. List, The Johns Hopkins University, for the Saturday session. Honorable mentions included Branch prize winners Harry Heyl, University of Delaware, and J. J. Erdos, Ohio Northern University. In addition to the foregoing, other Branch prize winners who participated in the competition were: E. D. Romito, University of Akron; R. C. Williams, Carnegie Institute of Technology; D. H. Brunner, Drexel Institute of Technology; A. V. Pohm, Fenn College; R. W. Zens, George Washington University; Robert Kudlich, Lafayette College; D. C. Caulkins, Lehigh University; W. J. Sheets, Ohio State University; J. P. Myers, Ohio University; W. D. Bolton, University of Pennsylvania; and Francis Haney, Villanova College.

Donald B. Chubb of the Lafayette College Student Branch headed the Committee in Charge of the Contest Meetings, while Professor J. G. Reifsnyder, Counselor, Professor F. W. Smith, G. W. Hoffman, Chairman of the Lafayette Branch, and students of the Branch were responsible for arrangements for the meeting. The Prize Paper Judging Committee consisted of F. M. Fuller (Chairman), H. E. Pearson, D. O Eschbach, and Dale Van Meter (Secretary).

District 2 Evolves Plan to Recognize Section Growth

Recognizing the fact that growth of individual Sections means growth of the Institute, a plan has been developed for measuring, recognizing, and stimulating the growth of the Sections in the AIEE Middle Eastern District (2), according to a recent announcement by C. G. Veinott, District Vice-President. (The Institute as a whole has shown an increase in membership in every one but six of its 66 years of existence; these six years occurred between 1929 and 1935.) The first of the new Growth Awards, an engraved certificate, was presented to the Pittsburgh Section on May 15, 1950 (see above). As explained by Mr. Veinott, the plan was developed as follows.

Prizes are offered to stimulate individual effort in the Institute. It thus was felt in District 2 that a prize competition should be set up among the Sections in order to stimulate the collective effort of members in a Section, operating as a Section. How should Section performance be judged? The plan would have to give small, as well as large, Sections a chance to win. The plan would have to be simple enough, and the formula automatic enough that all 16 Sections in the District could be rated absolutely impartially, without injection of individual bias. Preferably, the plan should lend itself to possible later use on a national scale. After considerable study, individually and collectively, by members of the District 2 Executive Committee, it was decided that growth was the most practical way to rate a Section, taking all factors into account. Accordingly the following formula was set up:

GROWTH = per cent net change in membership plus per cent change in over-all attendance (addition is to be algebraic)

Figures were obtained from National Headquarters; all members in counties involved in a territorial transfer during the year ending July 31, 1949, were excluded. (This exception was made to keep from penalizing a Section which agreed to have some of its territory transferred to another Section.) Following are the results:

Section	Per Cent Increase in Members	Per Cent Increase in Attendance	Total
Pittsburgh	14.6	229.4	244.0
Erie	8.3	97.9	106.2
Dayton	11.3	79.5	90.8
Canton	14.5	51.1	65.6
Cincinnati	15.1	28.8	43.9
District Average	11.3	15.7	27.8
National Average	8.4		

This plan is simple, impartial, and easy to administer without personal bias or prejudice. Moreover, it is probably impossible for any one Section to win consistently for a long period of time.

Prize Paper Awards Made at District 3 Student Meeting

Some 200 Student members from engineering schools in the New York Metropolitan Area attended the annual District 3 Student Branch Meeting on May 5 in the auditorium of the headquarters building of the New York Telephone Company. At the meeting the preliminary winners of the prize paper contest were called upon to give oral presentations of their papers.

D. W. Taylor, Chairman of the New York Section, presented the following prizes:

First prize—$25 to J. W. Corcoran of Manhattan College for his paper, "Physiology of Electric Shock"

Second prize—$15 to H. D. Wintle of The Polytechnic Institute of Brooklyn for his paper "A Low-Cost Induction Heating Unit"

Third prize—$10 to C. A. Benenson of The Polytechnic Institute of Brooklyn for his paper, "A Simplified Method for the Design and Analysis of Class-*C* Tuned Radio-Frequency Amplifiers"

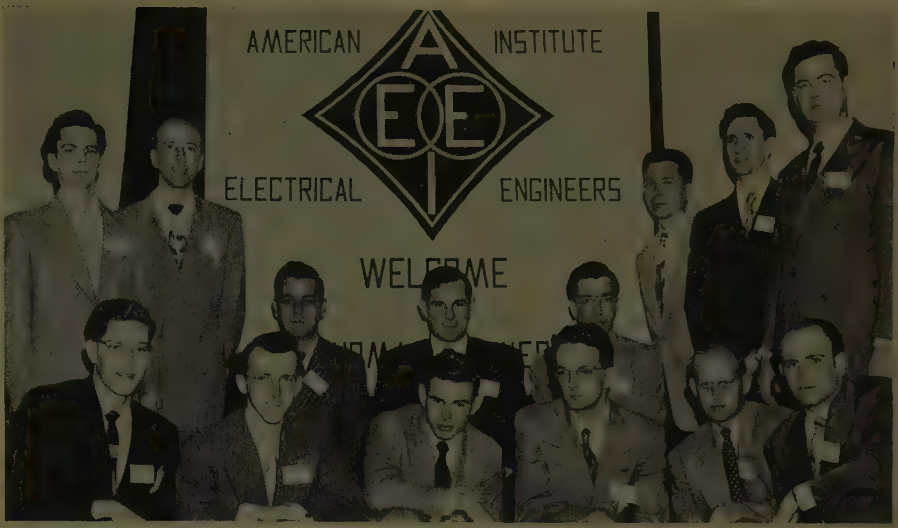
Additional Names Announced to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached

the age of 70 and paid dues for 30 years. A list of those who have become Members for Life during the preceding year is published annually in *Electrical Engineering*. Institute members enrolled as Members for Life as of May 1, 1950, are

Andrews, S. W.
Atkinson, K.
Bahm, J. F.
Beach, R.
Benedict, R. P.
Berg, A. L.
Birdsall, A. G.
Bitzer, O. F.
Brofos, E. A.
Brophy, J. J.
Brown, G. N.
Brown, G. O.
Champagne, L. J.
Clamer, G. H.
Cochrane, H. H.
Cone, D. I.
Cook, J. A.
Corey, M. M.
Corte, A. S.
Coup, F. T.
Cram, W. C., Jr.
Creecy, C. E.
Curtis, E. H.
David, B. W.
Davis, E. W.
Deininger, H. F.
de la Rosa, J. C.
Doerschuk, H. M.
Douglass, F. S.
DuBose, N.
Easler, J. M. T.
Ehrlich, L. B.
Eldredge, M.
Falloon, E. J.
Flaccus, G. W.
Fleming, A. P. M.
Franklin, M.
Friend, O. A.
Gates, A. B.
Gieselberg, G. H.
Gillon, G.
Gokay, W. M.
Gordon, C. S.
Graham, F. H.
Gray, H. L.
Greenleaf, M. C.
Gross, B.
Hamilton, J. L.
Harrington, C. A.
Hart, R. P., II
Heising, R. A.
Hitchcock, H. W.
Holcomb, R. D.
Hosfeld, D. C.
Hull, B. D.
Hull, R. H.
Hunt, R.
Iengar, N. N.
Jacobi, E. N.
Johnson, C. C.
Juhnke, P. B.
Just, J. S.
Kaiser, C.
Kammerman, J. O.
Kellogg, C. W.
Knight, I. W.
Langan, T. R.
Lougee, N. A.
Lunsford, J. B.
Lyle, F. W.
Magnuson, A. H.
Manning, J. H.
Markland, A. R.
McCarthy, J. B.
McEachron, K. B.
McNair, J. S.
Michetti, O. D.
Montabone, A. J. F.
Mount Edgcumbe, Earl of
Mullergren, A. L.
Murphy, W. V.
Nicholson, C. L.
Nicol, D. S.
Nye, H. V.
Orcutt, G. H.
Parker, K.
Parker, R. I.
Percival, H. S.
Petrie, A. E.
Radbone, V. J.
Ransdall, R. A.
Ransom, L. L.
Rickerby, W. J.
Robinson, L. N.
Rosch, S. J.
Rudd, H. H.
Savant, D. P.
Schumann, J. H.
Scovel, H. W.
Sheppard, H. S.
Short, F. A.
Sims, W. F.
Skove, W.
Smalley, D. F.
Smith, W. J.
Spaulding, J. G.
Stauflacher, E. R.
Stevens, J. C.
Stevens, P. S.
Sykes, C. S.
Travers, H. A.
Turner, W.
Underhill, J. D.
Voorhess, C. R.
Welge, D.
Wilkinson, K. L.
Wilson, A., III
Wines, H. D.
Wood, A. P.
Wurtele, J. S. H.
Wyatt, F. D.
Yerkes, E. P

District 7 Student Branches Meet



A meeting of the Student Branches within the AIEE South West District (7) was held at the University of Oklahoma, April 3–4, 1950. Those who presented papers at the meeting included, front row, left to right: J. R. Jaquet, Texas Technological College; Carroll Blewster, University of Arkansas; D. J. Freeman, Missouri School of Mines and Metallurgy; B. J. Whitley, Southern Methodist University; E. M. Hodges, University of New Mexico; B. L. Couch, Agricultural and Mechanical College of Texas. Second row: Leslie Terpening, Oklahoma Agricultural and Mechanical College; K. H. Powers, University of Texas; John Donahoo, New Mexico State College of Agriculture and Mechanic Arts; Miles Maxwell, University of Oklahoma; B. B. Nichols, University of Missouri; George Lagomarsini, University of New Mexico; Gilbert Fuller, University of Kansas

Vice-President Seely Visits Miami Section

A special dinner meeting of the AIEE Miami Section was held Monday evening, April 17, 1950, at the Biscayne Yacht Club, to welcome Vice-President W. J. Seely upon his annual visit to the Miami Section.

Professor Seely's visit was selected as the opportune time to launch preparations for the Southern District Meeting to be held in Miami, April 12–14, 1951. Forty-six enthusiastic members turned out to meet and hear Professor Seely tell about AIEE activities, and to plan for the meeting, the theme of which is "Vacation in Miami While Attending the Southern District Meeting." Following Professor Seely's talk on Institute activities which was noteworthy because of its humorous aspects, there was a general discussion of ways to make the 1951 convention the most outstanding District meeting in the history of the Institute. Here again Professor Seely was of great help in connection with the more vital needs of such a meeting.

Attending the April 17 dinner meeting of the AIEE Miami Section in honor of Vice-President W. J. Seely are, left to right, seated: E. E. Peeples, C. V. Booth, W. Lacy, E. F. Johnson, H. Pierce, Section Chairman C. H. Summers, Vice-President Seely, C. Whitmore, L. K. Hays, L. C. Wagner, J. Lambie, F. W. Knoepple, C. K. Lingo. Center row: W. H. Johnson, Dr. H. H. Sheldon, D. T. Rosselle, C. M. Broom, R. D. Cox, A. H. Nicholson, H. N. Towson, L. P. Browning, S. G. Kent, R. O. Bushnell, Robert Schwaner, O. Swanson, C. R. Stone, C. W. Whitmore, Jr., G. H. Shipley, M. Von Bose, J. G. Palatsky, J. B. Prime. Back row: A. Drexel, J. Bronaugh, R. Goodburn, E. L. Bivans, H. V. Street, J. P. Hanley, O. Ayers, R. Trimmer, G. Bell, W. B. Spellmire, T. Hibbard, D. S. Whitmore, W. H. Anderson, W. Brorien, D. R. Steele

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Group

Committee on Special Communications Applications. (*E. W. Kenefake, Chairman; L. A. Smith, Vice-Chairman; L. C. Holmes, Secretary.*) This committee is largely devoted to subjects which do not logically fall within the scope of the other communication committees, and is therefore devoted to many miscellaneous subjects. The subcommittees are endeavoring to find sources of technical papers on subjects of train control, centralized traffic control, caboose power supplies, communication, and train entertainment in the railroad field.

Committee on Aural Broadcasting Systems. (*E. G. Ports, Chairman; J. L. Middlebrooke, Vice-Chairman; M. L. Levy, Secretary.*) During the past year it was felt by this committee that its work covered a field that is relatively stabilized and that the shift of interest to television prevented its activities from expanding. After consideration it has been decided to combine this committee and the Committee on Television Broadcasting Systems for the new administrative year. This committee will be known as "Committee on Television and Aural Broadcasting Systems."

General Applications Group

Committee on Air Transportation. (*W. V. Boughton, Chairman; D. E. Fritz, Vice-Chairman; W. L. Berry, Secretary.*) The Aircraft Industries Association of America has issued a manual, in which 16 chapters are devoted to such significant topics as circuit protection, circuits for essential equipment, cable selection and routing, electric equipment selection and installation, maintenance, operation and inspection of electric equipment, electric system tests, and other related matter. This is the second series of AIA technical publications, developed by the Airworthiness Requirements Committee on Electrical Installations, and is available at the Aircraft Industries Association, Inc., 610 Shoreham Building, Washington, D. C., at a price of $1.75 per copy. The committee which undertook the work on this manual was composed of men who are all members of the AIEE, and several of them members of the Air Transportation Committee.

Industry Group

Research Subcommittee of Committee on Electric Welding. (*R. C. McMaster, Chairman.*) This subcommittee, which has been appointed during the past year, has selected the promotion and development of fundamental research on electric arcs for its major present activity. Particular attention will be directed toward fundamental research on high-pressure arcs (from about one-tenth atmosphere upward), which have features common to those of most welding arcs. By its activities the subcommittee hopes to increase the efficiency and usefulness of electric arc research. It is believed that the subcommittee can serve a useful purpose in this field through close co-operation with the AIEE Subcommittee on Electrical Properties of Gases, the Welding Research Council, and with other committees and agencies sponsoring electric arc research, without duplicating or competing with their activities, which, in general, embrace much larger fields of research. The attention of graduate students in the field of arc research will tend to insure a continuing supply of personnel skilled and interested in this field. Should the subcommittee be successful in its present outlined plans, further consideration might be given to more advanced activities, such as the promotion of Special Technical Conference on Electric Arcs. A questionnaire has been sent out to all co-operating members of the subcommittee for mutual use in co-ordinating research interests and in stimulating additional interest in fundamental arc research.

Committee on Industrial Control. (*G. W. Heumann, Chairman; J. A. Cortelli, Vice-Chairman; H. L. Palmer, Secretary.*) As the AIEE Middle Eastern District Meeting, to be held in Baltimore, Md., in October, will be in the heart of a heavily industrialized area, in which a considerable interest exists in heavy industrial-type control equipment, the committee is arranging for the presentation of several papers at this meeting. As the members of the committee feel it takes a full year to prepare for a worth-while technical session, they are already at work in planning a session for the 1951 Winter General Meeting, which it is expected will cover fundamental advances in the industrial control art. They are also planning to hold a committee meeting during the Iron and Steel Show in Cleveland in September.

Power Group

Committee on Switchgear. (*F. A. Lane, Chairman; H. V. Nye, Vice-Chairman; Otto Naef, Secretary.*) The subcommittees of this committee have devoted a large part of their activities to work on revision of AIEE Standards. Standard *50* for "Automatic Circuit Reclosers for A-C Distribution Systems" was published in September 1949 on a 1-year trial basis. The Guide for Application of Low-Voltage Air Circuit Breakers was published in pamphlet form and in the October 1949 issue of *Electrical Engineering*. The Joint Subcommittee on Out-of-Phase High-Voltage Switching completed its report, which was approved by the Switchgear Committee and recommended for printing.

Science and Electronics Group

Committee on Electronic Power Converters. (*C. C. Herskind, Chairman.*) Plans for the activities of this committee were outlined at a meeting of the Administrative Subcommittee held on September 12, 1949, in Pittsburgh, Pa. Since that time, the main efforts of the committee have been engaged in endeavoring to complete some of the projects initiated previously and in encouraging papers on new developments and applications. The results of these activities were reviewed at a meeting of the full committee held during the Winter General Meeting on February 1, 1950, in New York.

The committee has sponsored technical sessions at the three general meetings. The session at the Winter General Meeting featured large electronic d-c motor drives. At the Summer and Pacific General Meeting a number of papers on high-voltage rectifiers and power supplies for particle accelerators were presented.

The committee is planning to hold a Conference on Rectifier Cooling Systems during the fall in 1950. This conference will be devoted to cooling and corrosion problems.

Committee on Computing Devices. (*J. G. Brainerd, Chairman; W. H. MacWilliams, Jr., Vice-Chairman; W. C. Johnson, Secretary.*) This committee is organizing subcommittees for the purpose of producing technical papers and starting work on various subjects coming under its scope. It is also considering a long-range plan for having available papers for general meetings and District meetings a year in advance. The subject of preparing a bibliography has been discussed as possible future work, but it was agreed that co-operation with other societies was desirable and that plans should proceed unless a suitable bibliography by another organization makes such efforts unnecessary. At the last meeting of the committee, it was decided that tentatively the committee should leave the subject of fire-control type computers inactive.

AIEE PERSONALITIES.....

W. R. Smith (M'18, F'30), Safety Engineer, Electric Operating Department, Public Service Electric and Gas Company, Newark, N. J., has retired. Mr. Smith was born in Charleston, S. C., on February 23, 1885, and received the degree of Bachelor of Science in electrical engineering in 1906 and the degree of electrical engineer in 1928 from Clemson Agricultural and Mechanical College. Mr. Smith has been associated with the engineering and construction work of the electric system of Public Service Corporation of New Jersey since 1914. He became Safety Engineer in the Electric Department in 1938. Mr. Smith has actively served the Institute as a member of the Board of Examiners from 1930 to 1936 (Chairman, 1934–36), a member of the Board of Directors from 1942 to 1946, and as a member of the following com-

W. R. Smith

J. R. Read

mittees: Safety Committee (1939–50, Chairman 1943–45); Finance Committee (1942–46, Chairman 1944–46); Technical Program Committee (1935–37, 1943–45, Chairman 1935–36); Publications Committee (1935–36); Award of Institute Prizes (1935–37, Chairman 1935–36); Committee on Planning and Co-ordination (1935–37, 1944–46); Edison Medal Committee (1943–45); Standards Committee (1943–45); Headquarters Committee (1944–46); and Committee on Therapeutics (1945–49). He has also served the Institute as a Representative on the Electrical Committee of the National Fire Protection Association (1943–47), the National Fire Waste Council (1943–45, 1947–49), and the Alfred Noble Prize Committee (1936–37). Mr. Smith was also Chairman of the New York Section from 1938 to 1939 and Secretary of the Section from 1937 to 1938. He is a member of the American Society of Safety Engineers, a member and past chairman of the Accident Prevention Committee of the Edison Electric Institute and the Safety Code Correlating Committee of the American Standards Association. **A. F. Randolf** (A '24, M '25), Assistant to Chief Engineer, Electric Engineering Department, succeeds Mr. Smith as Safety Engineer in the Electric Operating Department. Mr. Randolph has been associated with the Public Service Electric and Gas Company since 1911. He started with the company as a timekeeper and successively held the positions of foreman, underground construction engineer in the Electric Distribution Department, and assistant to the division superintendent of the Central Division. In 1947, Mr. Randolph was appointed assistant to the chief engineer of the Electric Engineering Department. He is a member of the National Association of Corrosion Engineers.

J. R. Read (A '04, Member for Life), Chairman and President, Canadian Westinghouse Company, Ltd., Hamilton, Ontario, Canada, has retired. Mr. Read was born on October 24, 1879, in Virginia, and gained his initial electrical experience with the Sterling White Lead Company, Parnassus, Pa. He joined the Westinghouse Electric Corporation in 1899 as a student engineer and later assisted in the construction of the Niagara Falls generators. In 1901, Mr. Read was engaged as consulting electrician for various gold-dredging companies in California and later as electrical engineer for the Northern California Power Company, Redding, Calif. He joined Canadian Westinghouse in 1904 as a salesman and engineer in the district office at Vancouver, British Columbia. He became district office manager at Vancouver in 1907, and, in 1937, was transferred to headquarters at Hamilton, and elected vice-president in charge of manufacturing, patents, engineering, and plants.

Paul Cloke (A '12, F '38, Member for Life), Dean of the College of Technology, University of Maine, Orono, has retired. Dr. Cloke was born in Trenton, N. J., on September 4, 1882, and was educated at the New Jersey State Normal and Model School, Lehigh University, Columbia University, and the University of Maine. He received an electrical engineering degree from Lehigh University in 1905, a Master of Science degree from the same university in 1913, and a Doctor of Engineering degree from the University of Maine in 1934. Dr. Cloke's industrial experience has been with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), Public Service Company of New Jersey, the Signal Corps Radio Research Laboratory, Fort Monmouth, N. J., and the General Electric Company. He has instructed in physics and electrical engineering at many colleges and universities and received the appointment of Dean of the College of Technology at the University of Maine in 1926. He is a past vice-president of the Society for the Promotion of Engineering Education, a Past President of the Maine Association of Engineers, and a past chairman of the Arizona Committee on Allocation of Colorado River Water. Dr. Cloke has had many papers published in technical journals.

William Deans (A '16, F '30), Chief Engineer, I-T-E Circuit Breaker Company, Philadelphia, Pa., has been elected Vice-President in charge of engineering. He will be responsible for organization of the company's major engineering policies and co-ordination of all engineering matters among the company's various divisions and subsidiaries. Mr. Deans is a graduate of Cornell University, where he was an instructor in electrical engineering prior to World War I. During World War I he was a member of Thomas A. Edison's research staff. From 1918 until 1933 he was associated with the Sundh Electric Company. Mr. Deans has been Chief Engineer since 1933. **G. E. Heberlein** (M '46), Chief Engineer of Railway and Industrial Engineering Company (a subsidiary of I-T-E), Greensburg, Pa., has been appointed manager of the switchgear division of the parent company. He will have charge of sales, engineering, manufacturing, and associated services for large air circuit breakers and switchgear. Mr. Heberlein has been Chief Engineer of the Railway and Industrial Engineering Company since 1941. He is a graduate of Washington State College and was sales manager of the switchgear devices section of the Westinghouse Electric Corporation for four years.

A. J. Maslin (A '42, M '47), Advisory Engineer, Westinghouse Electric Corporation, Sharon, Pa., has been appointed Assistant to the Engineering Manager of the Transformer Division at Sharon, Pa. Mr. Maslin will continue to head the General Transformer Development Section and, in addition, will be responsible for transformer insulation development. Mr. Maslin joined Westinghouse after being graduated from the University of Michigan with a Bachelor of Science degree in electrical engineering in 1922. After completing the Westinghouse Electrical Design School he was assigned to the staff of J. F. Peters, consulting engineer for the company. In 1929, he was transferred to the Large Power Engineering Department of the Transformer Division and, in 1947, he was appointed Advisory Engineer for the Transformer Division. Mr. Maslin has written many papers and articles on technical subjects for professional publications and technical magazines and has been granted several patents on transformer developments. He is secretary of the Sharon (Pa.) Section of AIEE and is also a member of Sigma Xi and Tau Beta Pi.

F. A. Polkinghorn (M '39), Research and Development Director, Civil Communications Section, General Headquarters, Supreme Command Allied Powers, Tokyo, Japan, will return to Bell Laboratories, Inc., from which he has been on leave. Mr. Polkinghorn has been working with the Japanese in connection with research, development, manufacturing, and education in the telecommunications field. Primarily, his mission was to bring about a better sociological understanding of the value of telecommunications as well as to advise on the technical problems confronting both the government and the industry. The telephone and telegraph system of Japan is owned and operated by the Ministry of Telecommunications of the Japanese government. One of the important projects under Mr. Polkinghorn's personal supervision was reorganization of the Electrical Communications Laboratory, the research and development organization of the Ministry of Telecommunications. He is a Fellow of the Institute of Radio Engineers and a member of the American Association for the Advancement of Science, Phi Beta Kappa, Tau Beta Pi, Sigma Xi, and Eta Kappa Nu.

C. A. Bessey (A '03, M '29, Member for Life), Electrical Engineer, Pioneer Service and Engineering Company, Chicago, Ill., has retired. Born August 18, 1878, in Ames, Iowa, Mr. Bessey was graduated from the

University of Nebraska in 1897 with a Bachelor of Arts degree. He received the degree of Bachelor of Science in electrical engineering from the University of Nebraska in 1899. From 1899 to 1901 he was Assistant Professor of engineering at Oklahoma Agricultural and Mechanical College. In 1901, Mr. Bessey joined the General Electric Company, remaining with them until 1904 when he accepted a position with the Western Electric Company as an electrical draftsman. In 1905, Mr. Bessey accepted a similar position with Sargent and Lundy. He joined the Byllesby Engineering and Management Corporation (predecessor of Pioneer Service and Engineering Company) in 1909 and remained with the company until his retirement, except for the years 1917 to 1919, when he served as a first lieutenant in the Army of the United States.

W. C. Gilman (M '48), Partner, W. C. Gilman and Company, New York, N. Y., has been elected President and a Director of the Florida Power Corporation, St. Petersburg. Mr. Gilman was graduated with a Bachelor of Science degree from Massachusetts Institute of Technology in 1922 and the following year received a Master's degree from the same university. He also attended McGill University in Montreal, Canada. Mr. Gilman's industrial experience began with the General Electric Company. He has also been associated with the Central Hudson Gas and Electric Company and the Carolina Power and Light Company. In 1928, he was head of the utility investment department of the Equitable Life Assurance Society, New York, N. Y. In 1935, Mr. Gilman became director of the public utility division of the Securities and Exchange Commission in direct charge of carrying out the work involved under the Holding Company Act. He established W. C. Gilman and Company, a consulting engineering firm located in New York, in 1937.

D. R. Hull (M '48), Assistant Technical Director, International Telephone and Telegraph Corporation, New York, N Y., has joined the Raytheon Manufacturing Company, New York, N. Y., as Assistant to the Vice-President in charge of Equipment Divisions. Captain Hull, United States Navy (Retired), was graduated from the United States Naval Academy in 1925 and received a Master of Science degree from Harvard University in 1933. He was on continuous Naval service from 1921 to 1948 and, during World War II, he was Assistant Chief of the Bureau for Electronics, the senior Navy position in the electronics field. Captain Hull is a Fellow of the Institute of Radio Engineers and a member of the Acoustical Society of America, American Institute of Physics, and the Society of Naval Engineers. He also is a member of the Electronics Equipment Industry Advisory Committee Munitions Board.

C. C. Clymer (A '42), Application Engineer, Industrial Engineering Division, General Electric Company, Schenectady, N. Y., has been appointed Manager, Materials Handling and Testing Equipment Division of the General Electric Company's Industrial Engineering Divisions. Mr. Clymer is a graduate of the University of Colorado and joined General Electric in 1919. He became an application engineer in the Industrial Engineering Division in 1923. **M. A. deFerranti** (M '43), Manager, Materials Handling and Testing Equipment Division, has been appointed Assistant to the Manager of the Parts Division of the Aircraft Gas Turbine Divisions. Mr. deFerranti is a graduate of Sydney (Australia) Technical College and entered the employ of the General Electric Company in 1929. He became Manager of the Materials Handling and Testing Equipment Division in 1945.

H. R. Searing (A '20, F '30), President, Consolidated Edison Company of New York, (N. Y.) Inc., has been elected a member of the Board of Directors of the Commerce and Industry Association of New York, Inc. Mr. Searing received a Bachelor of Science degree in electrical engineering from Cooper Union and joined the New York Edison Company (predecessor of Consolidated Edison) in 1909. He successively became assistant engineer, general distribution manager, engineer of operation, and vice-president in charge of production and operation. He was elected executive vice-president in 1944 and was named president in 1949. He is a director of all the companies in the Consolidated Edison system. Mr. Searing is a member of Tau Beta Pi.

F. C. Holtz (A '16, F '47), Vice-President and Chief Engineer, Sangamo Electric Company, Springfield, Ill., has been appointed Technical Director of the engineering department. He will serve as a consultant to all members of the engineering staff, to the sales department, and to the company's customers. **J. S. Martin** (M '43), Assistant Chief Engineer, will provide engineering consultation to all members of the staff and laboratory. **W. C. Downing, Jr.** (M '35), Chief Engineer, Lincoln Meter Division, has been named an executive engineer (Thermal Devices). **W. W. Sherwood** (A '41), Research and Development Engineer, has been named an executive engineer (Electronic Apparatus).

H. A. Frey (A '28, M '43), Chief Development Engineer, Locke Insulator Corporation, Inc., Baltimore, Md., has been appointed Manager of Engineering. Mr. Frey is a graduate of The Johns Hopkins University and has been associated with Locke Insulator since 1926. He was Chairman of the Maryland Section from 1939 to 1940 and Secretary of the Section from 1937 to 1939. **W. S. Hill** (A '25, F '50), Vice-President, Engineering, has joined the Transformer and Allied Products Division of the Apparatus Department of General Electric Company, Pittsfield, Mass. Mr. Hill is a member of the AIEE Committee on Constitution and Bylaws and the Sections Committee. He has also been Secretary of the New York Section (1944–45).

E. W. Davis (A '15, F '34, Member for Life), Chief Engineer, Simplex Wire and Cable Company, Cambridge, Mass., has been appointed Director of Engineering. He will be succeeded as Chief Engineer by **G. J. Crowdes** (A '21, F '46), formerly Assistant Chief Electrical Engineer. Mr. Davis is serving the Institute as a member of the Board of Directors and the Board of Examiners. He is also the AIEE representative on the executive committee of the Engineers' Council for Professional Development. Mr. Crowdes was Chairman of the Boston Section of AIEE from 1934 to 1935 and Secretary of the Section from 1930 to 1933.

A. J. T. James (M '45), English Electric Company of Canada, Ltd., St. Catharines, Ontario, has been appointed Assistant Manager of Manufacturing. Mr. James has had over 20 years' experience in electrical engineering in Great Britain, New Zealand, and Canada. He is an associate member of the Institution of Electrical Engineers.

C. E. Johnson (A '09, F '25), President, Sterling Electric Motors, Inc., Los Angeles, Calif., has been elected Board Chairman of the company. Mr. Johnson, who has turned over active direction of the company to the new President, Earl Mendenhall, will devote his time to the further development and improvement of Sterling Electric Power Drives.

OBITUARY • • • • • •

Wynant James Williams (A '09, M '13, Member for Life), Head of the Electrical Engineering Department, Rensselaer Polytechnic Institute, Troy, N. Y., died May 1, 1950. Professor Williams was born in Port Dover, Ontario, Canada, on March 9, 1884, and was graduated from Rensselaer Polytechnic Institute in 1905 with a civil engineering degree and joined the faculty the following year. In 1910, he was sent to Germany for a year's study of that country's electrical engineering courses and his report was the basis on which Rensselaer's electrical engineering course was established. Professor Williams became head of the department of electrical engineering at Rensselaer in 1940. During World War II, he directed the development of a high-frequency shielding device for the National Defense Research Committee and the device was made available to the Armed Forces of the United States and Great Britain. Professor Williams had been active in the supervision of a recent development at Rensselaer of an all-electronic color television system, which is still in the stage of laboratory production. He was technical adviser to both the National Electric Light Association and the Travelers Broadcasting System of Hartford, Conn. He had also been associated with the American Radio Relay League and Croft Laboratory at Harvard University. Professor Williams was a member of the Society of Engineers of Eastern New York, the Society of Professional Engineers, Sigma Xi, and Tau Beta Pi.

A. Camp Streamer (A '10, M '41, Member for Life), retired, Westinghouse Electric Corporation, Pittsburgh, Pa., died May 4, 1950. Mr. Streamer was a veteran of 40 years with Westinghouse. Born in Boulder, Colo., November 23, 1885, he was graduated from the University of Colorado with a

Bachelor of Science degree in electrical engineering in 1907. Mr. Streamer joined Westinghouse in 1907 and, after handling inquiry work and Order Division functions, he became manager of the switchboard section of Supply Sales in 1915. In successive years he received the following appointments: assistant to the manager of Supply Sales (1920), assistant director of sales (1926), sales manager of Diversified Products (1931), manager of Diversified Products (1934), manager Transportation Division (1935), manager Switchgear Division (1936), and general manager of the East Pittsburgh works (1939). He was elected Vice-President in 1941. In 1943 Mr. Streamer was transferred from East Pittsburgh to the company's headquarters in Pittsburgh. He held an honorary Doctor of Engineering degree from the University of Colorado and from 1945 to 1946 served the Institute as a member of the Special Committee on Collective Bargaining and Related Matters. Mr. Streamer was a Past President of the National Electrical Manufacturers Association and a member of The American Society of Mechanical Engineers and Tau Beta Pi.

Vasco Roosevelt Parrack (A '25, M '31, F '49), Electrical Engineering Supervisor, Florida Power Corporation, St. Petersburg, died May 11, 1950. Mr. Parrack was born on August 22, 1901, in Roanoke, Va., and was graduated from the University of Virginia with an electrical engineering degree. From 1923 to 1924 he did transformer testing work with the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation) in Pittsburgh, Pa. In 1924, Mr. Parrack accepted a position in the distribution engineering department of the West Penn Power Company of Pittsburgh. From 1926 to 1930 he was an estimator for the Carolina Power and Light Company of Raleigh, N. C., and from 1930 to 1935 he was with the Tennessee Public Service Company in Knoxville. In 1935, Mr. Parrack accepted a position with the Tennessee Valley Authority and worked as an assistant electrical engineer at Wilson Dam in Alabama. Following periods of employment as a distribution engineer with the Carolina Power and Light Company of Raleigh and the Virginia Public Service Company of Charlottesville, he became Electrical Engineering Supervisor with the Florida Power Corporation in 1945. Mr. Parrack was a member of Tau Beta Pi.

Ruric Coin Mason (A '26, M '37), Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., died May 12, 1950. Mr. Mason was born in Bentonville, Ark., on September 6, 1903, and received a Bachelor of Electrical Engineering degree from the University of Arkansas in 1924. He continued his education at Princeton University where he received the degrees of Master of Arts and Doctor of Philosophy. Mr. Mason has been continuously associated with the Westinghouse Manufacturing Company since 1924 (then the Westinghouse Electric and Manufacturing Company). He has had several papers on gas discharges and mercury arc and vapor applications published in various technical publications. Mr. Mason had been a member of the AIEE Committee on Electronics since 1948 and a member of the Basic Sciences Committee since 1949. He had also served the Institute as a member of the Electrophysics Committee from 1933 to 1937, serving as chairman from 1936 to 1937, and as a member of the Technical Program Committee from 1936 to 1937.

Robert D. Hickok (M '16, F '32, Member for Life), President, The Hickok Electrical Instrument Company, Cleveland, Ohio, died recently. Born April 11, 1879, in Saybrook, Ohio, Mr. Hickok's first industrial experience was with the Electric Clock and Instrument Company of Atlanta, Ga., which later moved to Cleveland. Mr. Hickok developed and engineered the entire original line of electric instruments manufactured by The Hickok Electrical Instrument Company, with whom he had been associated since 1912. He held patents on several developments in electric indicating instruments and devices for testing radio tubes and receivers. Mr. Hickok was a member of the AIEE Committee on Instruments and Measurements from 1944 to 1947.

Willard C. Champe (A '25, M '35), Senior Electrical Engineer, Toledo (Ohio) Edison Company, died May 1, 1950. Born in Toledo on January 31, 1901, Mr. Champe was graduated from the University of Michigan with a Bachelor of Science degree in electrical engineering in 1923. After a year with the Westinghouse Electric Corporation as a graduate student engineer, he joined the Commonwealth and Southern Company at Jackson, Mich. Mr. Champe returned to the Westinghouse Electric Corporation in 1930 as a technical editor. From 1931 to 1936 he worked as assistant editor of *Electrical Engineering*, returning to Commonwealth and Southern in 1936. In 1938 he was employed by the city of Toledo as an electrical engineer assigned to special projects. Mr. Champe joined the Electric Auto Lite Company of Toledo in 1943, and, in 1947, returned to the utility industry. Mr. Champe was Chairman of the Toledo Section of AIEE from 1942 to 1943.

Haworth Lysander Brueck (A '42), Consulting Engineer, Brueck Engineering Company, Chicago, Ill., died April 11, 1950. Mr. Brueck was born in Decatur, Ill., on March 17, 1888, and was educated at Millikin University and Armour Institute of Technology. He received the degree of Bachelor of Science from the latter school. In 1916, Mr. Brueck was associated with the Wabash Railroad and, during World War I, he was a Captain in the 130th Infantry of the United States Army overseas. From 1919 to 1921 he was an engineer with the Illinois Traction System, Decatur, and from 1923 to 1940 he was a manufacturers' representative and a consulting engineer. In 1941, Mr. Brueck accepted a position as consulting engineer with the M. W. Kellogg Company, Chicago, and in 1942, he became Chief Electrical Engineer of the Sangamon Ordnance Plant of the War Department at Illiopolis, Ill. Mr. Brueck established his own consulting engineering business in Chicago in 1943.

Melvin C. Rose (M '46), Chief Engineer, Chesapeake and Potomac Telephone Company of Baltimore City (Md.), died April 23, 1950. Born on November 6, 1900, in Boston, Mass., Mr. Rose was graduated from Massachusetts Institute of Technology in 1921 with a Bachelor of Science degree in naval architecture. He entered the employ of The Chesapeake and Potomac Telephone Companies as a student engineer in the General Engineering Department, Washington, D. C., in 1921. When a general engineering organization was established in Baltimore in 1929, Mr. Rose was transferred to that city as Outside Plant Engineer. In succeeding years he was Transmission and Outside Plant Engineer, District Plant Manager, General Plant Manager, and Assistant General Manager before he was appointed Chief Engineer in 1946. As Chief Engineer, he was responsible for the planning and direction of the postwar expansion and building program of The Chesapeake and Potomac Telephone Company of Baltimore City throughout the state of Maryland. Mr. Rose had recently been elected to the executive committee of the Maryland Section of AIEE and he was a member of the Telephone Pioneers.

Alvin Augustus Miller (A '03, M '20, Member for Life), retired, Westinghouse Electric Corporation, died April 5, 1950. Mr. Miller was born in Dayton, Ohio, on June 1, 1874, and received the degree of Bachelor of Science in electrical engineering from the University of Nebraska in 1898. In 1898, he joined the Westinghouse Electric Corporation in Pittsburgh, Pa., as a draftsman and the next year he accepted a position as assistant engineer with the Bemis Brothers Bag Company. Mr. Miller returned to the Westinghouse Electric Corporation in 1900 as a salesman in the New York, N. Y., export office and transferred to the Seattle (Wash.) office in 1902. He remained with the company in Seattle until his retirement in 1939. Mr. Miller was Chairman of the Seattle Section of AIEE from 1908 to 1910.

Louis Frederick Woolston (A '20, M '24, F '29), Engineer, General Electric Company, St. Louis, Mo., died September 20, 1949. He had been with the company for 43 years. Born November 20, 1885, in Trenton, N. J., Mr. Woolston was graduated from Rutgers University in 1906 with an electrical engineering degree. His first position was with the General Electric Company as a student engineer at the original Stanley works in Pittsfield, Mass. After $2^1/_2$ years on this assignment, he joined the Engineering Department as a design engineer on transformers and regulators. Three years later, Mr. Woolston became assistant to the head of the Contract Service Department in Pittsfield, Mass. In 1913, he was transferred to the St. Louis office of the General Electric Company where he served for six years as assistant to the District Engineer. A change in the regional organization of the company in 1919 made the St. Louis office part of another district. At that time he was made Engineer of the St. Louis Office, the position he held until his death. Mr. Woolston was a past chairman of the St. Louis Section of AIEE and

he was a member of the Engineers' Club and Electrical Board of Trade of St. Louis.

James Cohn Waller (A '44), Electrical Design, James Stewart and Company, Inc., Chicago, Ill., died April 2, 1950. Mr. Waller was born in Chicago on June 15, 1890, and received a Bachelor of Science degree in electrical engineering from Illinois Institute of Technology in 1924. From 1924 to 1927 he did public utility appraisal work with Bemis and Company, Chicago, and from 1927 to 1935, worked in design and executive sales with the Knapp Brothers Manufacturing Company, Joliet, Ill. In 1941, he accepted an electrical design position with the Carnegie Illinois Steel Company of Gary, Ind., and in 1942 accepted a similar position with James Stewart and Company, Inc., remaining with the company until his death.

Louis Herman Ellerman (A '28, M '35), Assistant Superintendent, Testing Laboratories, Water and Power Department, Los Angeles, Calif., died March 14, 1950. Mr. Ellerman was born in Quincy, Ill., on January 22, 1897, and furthered his education at Armour Institute of Technology, Chicago, Ill. He entered the employ of the Commonwealth Edison Company in Chicago in the Meter Testing Department in 1915. After serving in the United States Marine Corps during World War I, Mr. Ellerman joined the El Paso (Tex.) Electric Company as manager of the Meter Department. In November 1922, he joined the Testing Laboratories of the Department of Water and Power at Los Angeles and attained the position of Assistant Superintendent in 1928.

Lewis George Martin (A '03, Member for Life), retired, The Okonite Company, Passaic, N. J., died April 1, 1950. Born August 27, 1869, in Woolwich, England, Mr. Martin had been with The Okonite Company since 1899 and had retired in 1937 as Vice-President of the company. Prior to this, Mr. Martin worked for Submarine Cable Companies from 1882 to 1899, and he had risen to the position of Station Superintendent in 1891.

Albert Stephen Hubbard (A '95, Member for Life), retired, Harry Alexander, Inc., died April 19, 1950. Mr. Hubbard was born in Greenwich, Conn., on August 4, 1873. From 1898 to 1918 he was Chief Electrical Engineer of the Gould Storage Battery Company of New York, N. Y. In 1918, Mr. Hubbard became associated with Harry Alexander, Inc., and remained with the company until his retirement in 1926.

MEMBERSHIP • • • •

Recommended for Transfer

The Board of Examiners at its meeting of May 18, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Bergvall, R. C., engg. mgr., Westinghouse Electric Corp., Pittsburgh, Pa.
Brooks, A. F., pres., The Southern New England Telephone Co., New Haven, Conn.
Crothers, H. M., vice-pres. & dean of engg., South Dakota State College, Brookings, S. D.
Darrow, L. H., bldgs. & equipment engr., New Jersey Bell Telephone Co., Newark, N. J.
Disque, R. C., dean of engg. & faculty, Drexel Institute of Technology, Philadelphia, Pa.
Glentzer, K. V., radio & special service engr., Illinois Bell Telephone Co., Chicago, Ill.
Kent, H. E., director of engg., Edison Electric Institute, New York, N. Y.
Levinger, D., vice-pres., Western Electric Co., Hawthorne Station, Chicago, Ill.
Mayott, C. W., asst. to pres., The Hartford Electric Light Co., Hartford, Conn.
Richardson, D. E., senior physicist, Armour Research Foundation, Chicago, Ill.
Ricketts, F. E., retired, 11 Osborn Ave., Catonsville, Md.
Satterlee, W. W., div. engr., Westinghouse Electric Corp., Sharon, Pa.
Schulz, E. H., chairman, elec. engg. dept., Armour Research Foundation, Chicago, Ill.
Spaulding, G. W., exec. vice-pres., Pennsylvania Water & Power Co., Baltimore, Md.
Teague, W. L., advisory engr., Westinghouse Electric Corp., Sharon, Pa.

15 to grade of Fellow

To Grade of Member

Albrighton, R. F., circuit engr., General Railway Signal Co., Rochester, N. Y.
Babbitt, G. W., elec. engg. dept., Canadian Brazilian Services, Ltd., Toronto, Ontario, Canada
Boesenberg, J. J., toll fundamental plan engr., Illinois Bell Telephone Co., Chicago, Ill.
Bourne, G. E., mgr., special products section, Canadian General Electric Co., Toronto, Ontario, Canada.
Brashear, H. E., staff engr., Southwestern Bell Telephone Co., Oklahoma City, Okla.
Brown, F. W., chief draftsman, Pacific Gas & Electric Co., San Francisco, Calif.
Carman, W. J., exchange fundamental plan engr., Illinois Bell Telephone Co., Chicago, Ill.
Cassidy, C. F., district wire & cable specialist, General Electric Co., Chicago, Ill.
Chamberlain, H. H., engr., General Electric Co., Lynn, Mass.
Chaney, L. P., elec. engr., Sinclair Rubber, Inc., Houston, Tex.
Coates, R. E., proposition engr., General Electric Co., Pittsfield, Mass.
Crawford, C. G., sales & service mgr., The Pelton Water Wheel Co., San Francisco, Calif.
DeMott, E. G., senior elec. engr., Weston Electric Instrument Corp., Newark, N. J.
Douglas, G. R., research engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
Fuller, F. C., Jr., engr., Illinois Bell Telephone Co., Chicago, Ill.
Gilbert, R. M., elec. engr., Westinghouse Electric Corp., Spokane, Wash.
Gohlke, A. C., chief elec. engr., Cleveland Electric Illuminating Co., Cleveland, Ohio
Guess, A. L., mgr., manufacturing div., D. M. Fraser, Ltd., Toronto, Ontario, Canada
Guy, J. R., senior engr., elec. engg. dept., The Cleveland Electric Illuminating Co., Cleveland, Ohio
Halleck, M. C., physicist, General Electric Co., Fort Wayne, Ind.
Heath, L. A., technical mgr., Morganite Inc., Long Island City, N. Y.
Hogue, L. J., engr., Commonwealth Edison Co., Chicago, Ill.
Hupp, R. L., design engr., General Electric Co., Fort Wayne, Ind.
Irion, A. D., asst. supt., shop & test div., Southern California Edison Co., Alhambra, Calif.
Jackson, A. R., Jackson & Jackson, 19 W. South Temple, Salt Lake City, Utah
Joerden, R. H., elec. engr., Arkansas Power & Light Co., Pine Bluff, Ark.
Jordan, W. G., Jr., industrial application engr., General Electric Co., Schenectady, N. Y.
Joseph, L. J., elec. instructor, Delgado Central Trade School, New Orleans, La.
Keener, C. E., head, missile guidance, Aero Electrical & Electronic Lab., NADC, Johnsville, Pa.
Kelley, E. J., elec. engr., Allis-Chalmers Mfg. Co., Youngstown, Ohio
Maihl, G. W., senior testman, Consolidated Gas Electric Light & Power Co. of Baltimore, Md.
Markley, F. R., director, vice-pres. Sun Oil Co., Philadelphia, Pa.
McAllister, D. H., district mgr., General Electric Co., Denver, Colo.
McGee, R. R., supervisor, engg. services, Trumbull Electric Co., Plainville, Conn.
McGillivray, A., consulting & application engr., Westinghouse Elec. Corp., Baltimore, Md.
McKenzie, M. T., asst. distribution supt., Savannah Electric & Power Co., Savannah, Ga.
Merritt, M. S., relay & protection engr., Tennessee Valley Authority, Chattanooga, Tenn.
Mitchell, H. H., asst. chief engr., Kelman Electric & Mfg. Co., Los Angeles, Calif.
Moorhead, G. H., Jr., elec. engr., Kelman Electric & Mfg. Co., Los Angeles, Calif.
Noedel, E. H., elec. supt. Brown & Root, Inc., Dumas, Tex.
Petrou, N. V., elec. engr., Westinghouse Electric Corp., Pittsburgh, Pa.
Petzing, W. N., mgr., General Electric Co., Shreveport, La.
Pimlott, J. R., senior elec. engr., David Taylor Model Basin, Washington, D. C.
Pope, K., metropolitan transmission engr., New England Telephone & Telegraph Co., Boston, Mass.
Powers, D. A., asst. prof., elec. engg., University of Toledo, Toledo, Ohio
Prechter, R. R., application engr., General Electric Co., Schenectady, N. Y.
Price, A. V., elec. engr., Ebasco Services, Inc., New York, N. Y.
Quinn, Q. Q., industrial power engr., Connecticut Power & Light Co., Waterbury, Conn.
Rhinehart, R. J., div. supt., Arkansas Power & Light Co., Pine Bluff, Ark.
Robinson, F. J., engr., Illinois Bell Telephone Co., Chicago, Ill.
Rose, A. M., div. transmission engr., American Telephone & Telegraph Co., Cleveland, Ohio
Rustebakke, H. M., asst. prof., University of Washington, Seattle, Wash.
Sallemi, J. B., engr., Commonwealth Edison Co., Chicago, Ill.
Schmidt, R. B., engr., Illinois Bell Telephone Co., Chicago, Ill.
Scruggs, D. W., elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Skinner, R. S., member, technical staff, Bell Telephone Labs., New York, N. Y.
Smith, J. H., mgr., apparatus div., Canadian General Electric Co., Ltd., Toronto, Ontario, Canada.
Street, H. V., chief engr., Florida Power & Light Co., Miami, Fla.
Uhden, C., elec. engr., Kaiser Aluminum & Chemical Corp., Spokane, Wash.
Welch, E. R., prof. & head, dept. of elec. engg., Howard Univ., Washington, D. C.
Weston, A. H., senior draftsman, engg. dept., Commonwealth Edison Co., Chicago, Ill.
Wiack, J. W., switchboard engr., Western Electric Co., Kearny, N. J.
Wicks, P., assoc. prof., elec. engg., University of Colorado, Boulder, Colo.
Wise, M., elec. engr., J. H. Wise Electric Co., Chicago, Ill.
Wolfenson, S. J., elec. engr., Ambursen Engineering Corp., Houston, Tex.
Wright, H. D., asst. engr., Pacific Gas & Electric Co., San Francisco, Calif.
Zimsky, J. J., chief mechanical engr., Pennsylvania Transformer Co., Canonsburg, Pa.

67 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before July 25, 1950, or September 25, 1950, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Acker, E. R., Central Hudson Gas & Elec. Corp., Poughkeepsie, N. Y.
Alvarez, W., General Elec. Co., Schenectady, N. Y.
Arnold, B. L., Interstate Telegraph Co., Bishop, Calif.
Bender, W. W., Glenn L. Martin Co., Baltimore, Md.
Brant, B., Detroit Edison Co., Detroit, Mich.
Cannon, M. W., General Elec. Co., Schenectady, N. Y.
Caranfil, N. G., c/o Mr. St. Irimescu, 405 E. 54th St., New York, N. Y.
Cornell, B. S., New York Telephone Co., New York, N. Y.
Costello, J. M., Univ. of South Carolina, Columbia, S. C.
Dupre, H. P., Burndy Engineering Co., New York, N. Y.
Durst, J. F., U. S. Navy Electronics Lab., San Diego, Calif.
Epstein, S., Univ. of Buffalo, Buffalo, N. Y.
Gervais, W. A., General Elec. Co., Schenectady, N. Y.
Harris, E. V., c/o Jose Margues, Box 1025, Rio de Janeiro, Brazil, S. A.
Howard, P. L., Bureau of Standards, Washington, D. C.
Kareem, M., N. W. Railway, Lahore, Pakistan
Kelly, E. L., Consolidated Gas Elec. Lt. & Pr. Co. of Baltimore, Baltimore, Md.
Kersting, W. J., Public Service Elec. & Gas Co., Newark, N. J.
Kressler, C. H., Gannett Fleming Corddry & Carpenter, Inc., Harrisburg, Pa.
Lanphier, C. H., Sangamo Elec. Co., Springfield, Ill.
Laske, E. J., 3592 Richmond St., Philadelphia, Pa.
Paul, O. J., Ralph M. Parsons Co., Los Angeles, Calif.
Peterson, M. L., American Tel. & Tel. Co., Chicago, Ill.
Raiford, W. C., Corps of Engineers, Dept. of the Army, Nashville, Tenn.
Rigby, W. H., Watson & Hart, Greensboro, N. C.
Sassman, C. E., West Penn. Power Co., Pittsburgh, Pa.
Schmitz, A. W., General Elec. Co., Schenectady, N. Y.
Sharma, L. R., Military Engineering Service (Govt. of India), West Bengal, India
Umberger, J. R., Boeing Airplane Co., Seattle, Wash.
Wilkinson, H. N., Seaboard Railroad, Savannah, Ga.

30 to grade of Member

NBS Develops Electron-Optical Method for Mapping Electric Field of Magnetron

An accurate sensitive technique for experimentally determining the electric-field distribution and space-charge density within a magnetron has been developed by Dr. D. L. Reverdin at the National Bureau of Standards in Washington, D. C. The new method, which is also well suited to investigations of electron-optical lenses, gas discharge, and other space-charge problems, is a modification of the electron-optical shadow technique recently developed at the Bureau for the quantitative study of minute electric and magnetic fields. A magnetic lens is used to produce shadow images of two fine-wire screens placed at either end of the magnetron in the path of an electron beam. Then, from the distortion in the shadow network caused by deflection of the electron rays as they pass through the magnetron field, the radial electric field is computed. These results are used to obtain the space-charge distribution.

The high space-charge density within a magnetron is known to have an important bearing on performance. However, very little is actually known concerning the electric-field distribution and space-charge configuration within the tube. Although the problem has been investigated theoretically by many workers, the formidable mathematics involved have not permitted an exact solution, and the various simplifications of the theory that have been suggested have led to widely divergent results. Attempts at direct measurement have also proved unsuccessful because the very critical symmetry of the field under study was disturbed. A promising approach to the problem has now been provided by the method developed at the Bureau. This technique has been used to map the charge distribution within a cut-off or steady-state magnetron. Further application to oscillation magnetrons should lead to a much better understanding of their operation and should yield information of considerable value to the engineer who is interested in designing improved types of magnetrons or in predicting the performance of existing types.

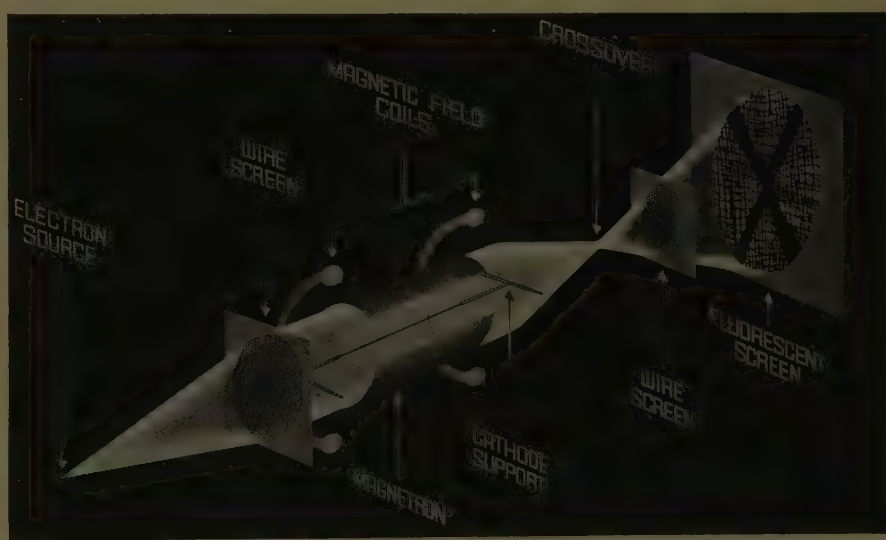
The Bureau's method uses an electron beam as a probe but keeps the charge density of the probe beam small compared to the space charge in the magnetron. Thus, the field under study is undisturbed. An electron gun sends the beam axially through the tube. Coaxial coils surrounding the magnetron provide a homogeneous magnetic field for the operation of the magnetron and, at the same time, act upon the beam as a convergent magnetic lens, bringing it to a focus beyond the tube. Two fine-wire screens are placed in the path of the electrons, one just in front of the magnetron, the other just beyond the back focus of the beam. A complex shadow pattern due to the two wire screens is then formed on a fluorescent screen. When the d-c potential across the magnetron is zero, the pattern is undistorted. However, when an electric field is applied to the magnetron, the shadow network on the fluorescent screen becomes quite distorted. Theoretical analysis of this effect has related the distortion of a given part of the pattern to the intensity of the electric and space-charge fields in the corresponding region of the magnetron.

In practice, photographs are taken of the shadow network, both in the undistorted and distorted form. The changes in the paths of the electron rays as they pass through the magnetron are then determined from measurements of the shadow patterns and the geometrical constants of the system, such as the positions of both wire screens, the magnetron, the electron source, and the number of meshes per unit length of the wire screens used. From the deflection of an electron ray entering the magnetron at a given radial distance from the center, the strength of the electric field in the corresponding region of the magnetron is computed.

In comparison with previous methods using a pencil beam of electrons but no optical system, this method is much more sensitive and accurate. It also has the advantage of giving a complete field map in a very short time. The principal source of error lies in the uncertainty regarding the configuration of the electric fringe field at either end of the magnetron under space-charge conditions.

The Bureau's study of the field within a steady-state magnetron indicates that the actual space-charge distribution differs con-

Shadow pattern obtained at the National Bureau of Standards by electron-optical mapping of the space-charge density within a magnetron. The lack of sharpness in the ring region provides a visual indication of the noise within the magnetron. The small black spots are dots of Aquadag painted on the wire screens to aid in identification of parts of the pattern



Perspective drawing illustrating the principle of the new electron-optical technique developed at the National Bureau of Standards for experimentally mapping the electric-field distribution within a magnetron. A magnetic electron lens, the field of which is produced by a current flowing through the two coaxial coils surrounding the magnetron, is used to produce shadow images on the fluorescent screen of two fine-wire screens placed in the path of an electron beam. The same magnetic field serves for the operation of the magnetron. Deflection of the electron rays by the field within the magnetron causes distortion in the shadow network, from which the electric-field and space-charge distributions are computed. The X-shaped figure on the fluorescent screen is the shadow image of the two transverse rods which support the cathode filament within the magnetron. The spiral paths induced in the electron beam by the magnetic lens causes these images to be rotated with respect to the cathode support

siderably from that predicted by theorists. A number of different shapes of space-charge configuration were observed which are closely related to the symmetry of the magnetron. A certain lack of sharpness noted in the patterns gave a visual indication of the noise in the tube. This suggests further extension of the method to learn more about the problem of noise in an oscillating magnetron.

Stevens Offers Graduate Assistantships and Fellowships

The Graduate School of Stevens Institute of Technology has established a series of graduate assistantships opening in the academic year 1950–51. Appointments will be available in the fields of chemistry and chemical engineering, physics, and metallurgy. The school plans to offer assistantships in other subjects from time to time. Also, a Westinghouse Fellowship in Engineering was announced which provides for graduate study in either chemical engineering, electrical engineering, mechanical engineering, or metallurgy. The stipend is $1,000 per year from which graduate tuition must be paid.

Both the assistantships and the fellowship are open to graduates of Stevens and of other institutions who wish to study in the New York metropolitan area. Graduate assistants will be appointed for a 9-month period and will be expected to devote a minimum of 18 hours per week to departmental duties including instruction. Assistantships carry a stipend of $90 per month and remission of graduate tuition and fees in not more than three courses per semester. Appointments are for one academic year and carry eligibility for reappointment at slightly increased stipends.

A limited number of Experimental Towing Tank fellowships are open each year to college graduates who are interested in learning the techniques of model tests of ship and flying-boat hulls as well as acquiring experience in the broader principles of hydrodynamic research in which the experimental towing tank is engaged.

Further information and applications may be obtained from the Director of the Graduate School, Stevens Institute of Technology, Castle Point, Hoboken, N. J.

Reeves Instrument Develops Electronic Analogue Computer

An electronic simulator, known as the REAC (Reeves Electronic Analogue Computer), has been developed by Claude Neon, Inc., in its research center, the Reeves Instrument Corporation, New York, N. Y.

The REAC "tests" airplanes before they have been built, automobiles before they have been assembled, and chemical processes before they have been put into operation. It is the first computing equipment of its type to be sold on a large scale and is now in use by aircraft manufacturers, laboratories, and universities.

The REAC is essentially a "simulator" of various electronic devices, machines, or vehicles and in operation gives the answer to problems which are met, by simulation, under any number of different conditions.

What is actually done when an equation is set into the REAC is to simulate the system to which the equation applies. For example, using aerodynamic relationships expressed in terms of ordinary, initial-valued linear and nonlinear simultaneous differential equations, the REAC can be set so that it simulates the flight of an aircraft. The effect of contemplated design changes or the design that will give optimum performance can be determined without actually building an aircraft or model. Control equipment can be tested by using the REAC to simulate an aircraft. Similarly, chemical and other industrial processes can be simulated and controlled.

The standard REAC in appearance looks like any conventional type of control panel. It consists of the computer unit, servomechanism unit, recording unit, and associated power supplies.

Stanford Research Institute Develops New TV Transmitter

A new type of transmitter that will aid in opening additional air lanes for television has been announced by Stanford (Calif.) Research Institute. The transmitter has been designed for sending signals in the ultrahigh-frequency region of 475 to 890 megacycles, recently authorized by the Federal Communications Commission for experimental television broadcasts.

Now installed at experimental station *KM2XAZ* of Long Beach, Calif., the transmitter operates on 530 megacycles. It radiates an entirely standard amplitude-modulated picture signal of good quality. It does so in a manner permitting the attainment of a very high power ultrahigh-frequency transmission more economically than by any other presently known system.

While the *KM2XAZ* transmitter is at present radiating only 150 watts of power, it is capable of being amplified to powers in the tens of kilowatts using relatively simple radio-frequency amplifiers. This is achieved by applying for the first time to television a system of modulation known as "phase-to-amplitude."

The phase-to-amplitude modulation system reaches high-power levels with presently available ultrahigh-frequency tubes which are difficult to amplitude-modulate by any other means. The special transmitter can also make use of the recently developed tubes such as klystrons, resnatrons, and traveling-wave tubes.

Special phase-modulator tubes have been designed by the Vacuum Tube Laboratory staff at Stanford Research Institute for a new phase-to-amplitude television transmitter operating on 530 megacycles. They incorporate the modulating jobs of several conventional ultrahigh-frequency tubes into one tube. This model is shown while still connected to the vacuum pumps during laboratory processing

The heart of a transmitter of the new type is the phase-modulator unit, which serves to advance the phase of one of the two signal channels of the system by exactly the same amount that it retards the phase of the second channel. A unique arrangement of conventional ultrahigh-frequency tubes has been employed to perform this function.

Still another innovation in the work on the transmitter has been the development of a vacuum tube which does the modulation job of several conventional tubes in one. Several models of the special phase-modulator tube have been built and tested. Thus far these tubes have had the limitation of low power output. If they can be developed to the point of operation at higher power levels, staff engineers believe the complexity of the phase-modulator unit can be greatly reduced and its performance improved.

Future Meetings of Other Societies

American Chemical Society. Chicago Section—Sixth National Chemical Exposition. September 5–9, 1950, Chicago Coliseum, Chicago, Ill.

First United States International Trade Fair. August 7–20, 1950, Navy Pier, International Amphitheatre, Coliseum, and Arena, Chicago, Ill.

Illuminating Engineering Society. National Technical Conference. August 21–25, 1950, Hotel Huntington, Pasadena, Calif.

Institute of the Aeronautical Sciences. Annual Summer Meeting. July 12–14, 1950, IAS Western Headquarters Building, Los Angeles, Calif.

Institute of Traffic Engineers. Annual Meeting. September 24–27, 1950, Commodore Hotel, New York, N. Y.

Instrument Society of America. 1950 Instrument Conference and Exhibit. September 18–22, 1950, Memorial Auditorium, Buffalo, N. Y.

International Conference on Large Electric High-Tension Systems (CIGRE). 13th Session. June 29–July 8, 1950, Paris, France.

National Conference on Industrial Hydraulics. Sixth Annual Conference. October 18–19, 1950, Sherman Hotel, Chicago, Ill.

Society of Automotive Engineers. Transportation Meeting. October 16–18, 1950, Hotel Statler, New York, N. Y.

New Water-Purification Process Gives Spring-Water Taste

An instrument known as a "G-E dew-point recorder" and a new water-purification process that uses no unpalatable chemicals is giving a spring-water taste to water from the Schuylkill River. The Welsbach Corporation plant, located in Philadelphia, Pa., is the largest water-purification installation in the United States using ozone to kill river-water bacteria.

In the ozone process, outside air is compressed, cooled, and dried. Then the air is blown past banks of metal plates charged with high voltage. The electricity from the plates causes an electrostatic discharge to take place within the passing air, producing ozone, an unstable form of oxygen.

As the air passes over the metal plates

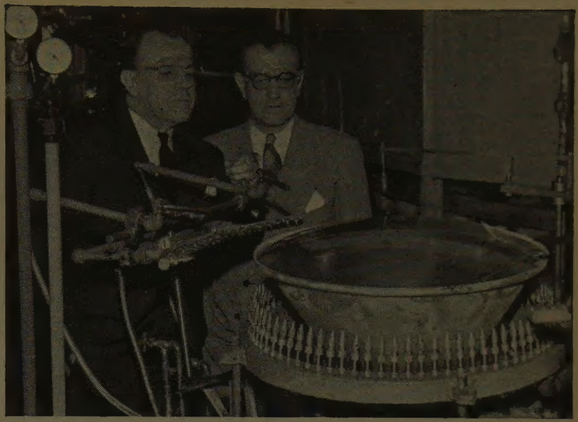
which cause the electric discharge, it must have a very low moisture content. To assure that moisture in the air remains constant during the process, the dew-point recorder is used. Designed and built by engineers of the General Electric Company's General Engineering and Consulting Laboratory at Schenectady, N. Y., the instrument gives a continuous record of air dryness by measuring and recording the temperature at which moisture in the air condenses on a mirror's surface.

The ozone is bubbled through river water from which the sediment has been allowed to settle. Being an unstable gas, the ozone breaks down again into ordinary oxygen and kills the bacteria in the water.

Finally, the water is filtered and pumped into city mains, with only a trace of chlorine added to protect its purity until it reaches the city's water faucets.

GE's New 24-Inch Picture Tube

The General Electric Company's new 24-inch television picture tube is shown mounted on a glass-to-metal cone sealer. The tube features a dark face plate which improves contrast and detail and an aluminum-backed fluorescent screen which increases picture brightness and permits operation at lower voltages



High School Seniors Awarded Westinghouse Scholarships

Ten of the nation's outstanding high school senior men have been awarded George Westinghouse scholarships valued at $2,400 each to be applied toward a degree in engineering or the physical sciences at the Carnegie Institute of Technology.

The winners were selected from 1,804 applicants representing all 48 states and the District of Columbia. Of this number, 723 students underwent a 6-hour engineering aptitude test given by the Education Testing Service of Princeton, N. J. The final awards were made for mental ability and engineering aptitude, and for qualities of leadership as shown in extracurricular activities and in community affairs.

The scholarships, which provide $300 for each of the eight semesters at Carnegie Institute of Technology, were established in 1937 in honor of George Westinghouse, founder of the Westinghouse Electric Corporation. Since then these scholarships have provided financial assistance for 130 men who sought careers in engineering and science.

The winners are: W. H. Arnold, Bellmore, N. Y.; K. W. Buckley, Jr., Bremerton, Wash.; R. W. Detenbeck, Kenmore, N. Y.; R. M. Durstine, Ellwood City, Pa.; T. I. Kirkpatrick, San Diego, Calif.; J. T. Mullhaupt, Warren, Pa.; V. W. Pratt, Idaho Falls, Idaho; J. F. Ready, St. Paul, Minn.; P. L. Smith, Jr., St. Joseph, Mo.; and J. D. Walecka, Wauwatosa, Wis.

New Brazilian Power Line. A new high-voltage power transmission line will be erected in Brazil, connecting the hydroelectric plant of Salto Grande on the Santo Antonio River with Santa Luzia, which will become the first industrial center of the State of Minas Geraes. An electric substation will be erected in Itabira, between the two terminal points. The voltage of the line is 161,000 volts, and its length of approximately 100 miles will require 350 towers, the total weight of which will be about 900 metric tons. The towers are of a special design, following the European technique developed in the last 20 years. This new method of steel construction employs tubular structures either alone or together with customary shapes. It results in a better utilization of the materials, because it allows a higher stress and consequently a reduction in the total weight of the towers. Weight in this case is an important factor because good roads are lacking and transportation conditions in general are very poor. The delivery schedule of the new line is 18 months. The work is a part of the *Plano de Recuperacao Economica e Fomento da Producao*, the Brazilian Government's plan for the industrialization of new areas. The construction of the towers and the complete assembly will be done by ELINA (Electro Industrial Argentina), Buenos Aires, an electrical division of TECHINT (Compania Tecnica Internacional).

Heat-Power Apparatus Standard. A compilation of 44 "Graphical Symbols for Heat-Power Apparatus" has been approved by the American Standards Association as a new American Standard (*Z32.2.6-1950*). The Standard is the sixth of a group of Standards developed as revisions and expansions of an existing Standard, "American Standard Graphical Symbols for Use on Drawings in Mechanical Engineering (*Z32.2-1941*). Many leading power companies and their representatives throughout the country were consulted and a careful study was made to avoid conflicts with symbols being assembled by committees in allied fields. Clarity, simplicity, and nation-wide acceptance were basic considerations in assembling the symbols. Several symbols that are being used only in limited areas were omitted. Sponsors of the new Standard are AIEE and The American Society of Mechanical Engineers. Copies of the Standard are available from the American Standards Association, 70 East 45th Street, New York 17, N. Y., at 35 cents a copy.

Annual Meeting of the ASTM. New testing and scientific equipment featured the 1950 Exhibit of Testing Apparatus and Related Equipment in Atlantic City, N. J., during the week of June 26 when the American Society for Testing Materials had its 53d Annual Meeting. Leading manufacturers and distributors of instruments and laboratory supplies emphasized the continued progress being made in providing the research and testing engineers with suitable facilities for evaluating the properties of all kinds of materials. In addition to the improved types of physical and chemical testing instruments, many of the newer types of spectographs, nondestructive testing instruments, and equipment for stress analysis were featured.

Volcanic Energy as Source of Electric Power. An oil-well drilling rig made by the National Supply Company, Pittsburgh, Pa., is being shipped to Larderello, Italy, where it will be used to drill for steam. At Larderello, volcanic energy is being used as a source of electric power. Water seeps through semiporous rock down to a bed of hot lava where it is heated and forms a well of steam. When the well is tapped, the steam rushes to the surface and is carried through insulated pipes to power plants where it drives turbines for generators producing more than 200,000 kw. Larderello is also Western Europe's only source of boric acid and borax. The same steam which is used for generating electric power is sent through purifiers after it rises to the surface and the vapors which contain minerals are run through condensation towers where they yield boric acid and borax.

Geddes to Retire From RMA. Bond Geddes, Executive Vice-President of the Radio Manufacturers Association, will retire August 1, 1950, after nearly 23 years of service, but will be advisory consultant to the association for a number of years. Mr. Geddes was elected Executive Vice-President and General Manager on November 1, 1927, and his experience spans the industry's history. He was formerly manager of the United Press Bureau in Washington, and also chief of the Associated Press capitol staff. He is a member of the Federal court bar of Washington, having been graduated in law from Columbian College (now George Washington University), and is also a member of the Federal Communications Commission bar.

8¹/₂-Ounce 400-Cycle Converter. Large economies in space and weight in servomechanisms and electronic and electric

apparatus is provided by a new $8^1/_2$ ounce 400-cycle converter manufactured by the industrial division of the Minneapolis-Honeywell Regulator Company. The new converter can be used with any system which converts low-power d-c signals, as low as one microvolt, to 400-cycle alternating voltages. It is useful for voltage-error measurements or null detection. The converter will function at high altitudes in various electronic and electric apparatus and in servomechanisms for aircraft and guided missiles.

Capacitors With Glass Ribbon Dielectrics. Through the use of glass ribbon in the place of mica sheets in miniature capacitors, the United States Army Signal Corps expects to achieve a saving of 50 to 70 per cent in manpower during mass production. The glass-ribbon capacitors were developed by the Corning Glass Works of Corning, N. Y., under a Signal Corps research and development contract. Glass ribbon is used as the dielectric and aluminum foil as the electrodes. They are sealed in a glass case that is impervious to atmospheric moisture and other troublesome climatic effects. The glass capacitors are one-fifth to one-sixth the size of equivalent mica capacitors and the large manpower saving in mass production is foreseen because the glass ribbon will be of uniform thickness, whereas sheets of mica now have to be hand-sorted for uniform thickness and quality.

Electrical Safety of Modern Plastics. Powerful short-wave radio equipment, capable of reaching around the world, has been muffled within a small room by The Johns Hopkins University scientists testing the electrical safety of modern plastics. At the University's Institute for Co-operative Research, the high-voltage transmitter goes "on the air," but its signals go only six feet, subjecting samples of plastic materials to tests that have uncovered new data of both practical and scientific importance. The power of the high-frequency oscillator has been bridled by lining the 7- by 15-foot room with copper sheathing. When the equipment is at work, no one can remain in the room, yet a sensitive receiving set in an adjacent work shop is unable to pick up the faintest signal from the oscillator.

Puerto Rico's Electric Power Development. The Puerto Rico Water Resources Authority is constructing a $14,000,000 steam-generating plant which will be completed early in 1951. The power plant will be in three units of 20,000 kw each. Ultimate capacity of the plant will be 100,000 kw. It is another project in Puerto Rico's program to keep ahead of demand for electric power, now being produced in excess of 500,000,000 kilowatt-hours annually for industrial, residential, and wholesale consumers.

Water-Repellent Ignition Seal. Research and improved development has been completed for the General Motors Corporation's Coach and Bus Division on a water-repellent ignition seal to be distributed by the General Motors Corporation. The product, developed by the Sherolite Chemical Corporation, New York, N. Y., functions primarily as a protective coating on metals, wires, and electric systems against such corrosions and damages as are effected by water, condensation, leakage, acid, fungus, and rust. As a water-repellent coating, Sherolite is a preventative of the afore-mentioned hazards, and in its early form accomplished the task of protecting marine, aviation, and vehicular engines and metal parts from the ravages of weather and heavy duty during World War II. In its improved capacity, Sherolite is a thin, workable liquid applicable to metals and electric wires or connections by spraying or brushing at room temperature. It dries tack-free in eight minutes and hard in 45 minutes, forming a lasting coat. Since it contains no petroleum derivative, Sherolite neither attacks nor softens even synthetic rubber such as hose connections, grommets, or wiring insulation of low rubber content, but protects these substances by repelling all liquids or corrosive elements.

Proposed Standard for Radio Noise Meter. "Proposed American Standard Specifications for Radio Noise Meter, 0.015 to 25 Megacycles Per Second," National Electrical Manufacturers Association Publication Number *102-1950*, sponsored by both the Radio Manufacturer's Association and the National Electrical Manufacturers Association, has been published for one year's trial use. It covers radio noise and field intensity meters intended for general factory and field radio-noise and field-intensity measurements. The appendixes describe the methods for the measurement of radio-noise influence voltage and the method of determining charge and discharge times of the detector circuit. After final revision, approval, and publication the Standard will supersede the report on "Method of Measuring Radio Noise," National Electrical Manufacturers Association Publication Number 107. Copies are available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y., at 65 cents per copy.

Periodical Back Issues Available. The Electronics Research Publishing Company, Inc., New York 13, N. Y., has arranged with the various publishers of domestic and foreign scientific periodicals, journals, proceedings, and technical house organs, to supply back issues of their publications. The charge is the same as that of the publisher of the periodical. In the event that back issues of a publication are not available, a photostatic reproduction of the article required can be supplied. This service is restricted to those publications that have granted permission to reproduce their material. A nominal fee is charged.

Television Station for Mexico. Mexico's first television station, equipped with a 5-kw transmitter and associated studio and mobile pickup units, is scheduled to go on the air in Mexico City this summer. The station is owned and operated by Television de Mexico, S. A., and will operate on channel 4.

Tabor to Head Franklin Institute Committee. Lewis P. Tabor, senior research engineer in the Franklin Institute Laboratories for Research and Development, Philadelphia, Pa., has been elected chairman of the institute's Science and Arts Committee which is responsible for choosing the scientists to whom special institute medals are awarded each year. Mr. Tabor will be the 66th chairman of this committee, replacing Laurence LePage of the Adrian Bauer Advertising Agency who resigned to undertake other duties for the institute. He is a graduate of the Massachusetts Institute of Technology.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Institute Policy

To the Editor:

There is currently considerable tarradiddle and hoop-la about engineers taking part, or not taking part, in national affairs. To my mind, a little clear thinking on basic points is needed. What is an engineer? He is a citizen; he is an educated citizen; he is a technically educated citizen, whose work consists in the study and application of physical laws to physical objects or systems.

As a citizen, the engineer is obligated and privileged to take an active interest in his government, to any extent he may desire: discussion with other citizens, work for a political party, association with various civic organizations, attempt to win election to public office. To the extent that he is educated, he is better fitted to exercise these privileges and fulfill his obligations.

On the score of his technical education, however, the engineer has no claim to competence in the political, economic, or social field. Engineering education deals with, and is directed toward an understanding of, the physical world: mechanics, electrodynamics, chemistry. Mathematics is included as a tool, for the expression of that quantitative result which is the end product of any engineering investigation or project. The primary object of the engineering curriculum is to graduate men who are reasonably competent in the physical sciences, and the student devotes all his energies toward the attainment of that object.

There is no basis in the education and training of an engineer for any claim that he is competent in a field other than engineering. In fact, the engineer himself should be quick to deny such a claim; his experience should teach him that competence in any field is attained only by study and hard work. It is frequently said that engineers might do a good job of running the country because they are accustomed to dealing with facts, and act on the basis of reasoned and logical conclusions. The premise here is true, but the conclusion is erroneous. Engineering decisions are usually reasoned and logical because they are made after consideration of a number of definite facts; well-established facts, manipulated in accordance with well-known mathematical rules, studied in the light of proved physical laws. What is the material upon which decisions are based in the politico-economic field? Human beings are the basic material, and the ways in which they act.

Economic laws, so-called, are nothing but an accumulation of data regarding the actions of men, for if man did not exist, there could be no "economics." The data are unsystematic, not correlated with anything, and are of little practical value. There is no way to determine the reliability of the data or of the principles that may be derived therefrom, since it is impossible to set up laboratory tests as we do in engineering. We are told, on the one hand, that we may not trifle with engineering laws. But if there are such laws, why cannot we make use of them as we do of our physical laws? We are told, on the other hand, that it is possible to predict and control social and economic phenomena. In that case, the engineer has no function, because he has not studied these laws.

Not even the most rash social "scientist" would claim that any rules exist by which the actions of any group of men, or of any nation, could be calculated and predicted to a given degree of accuracy—to the same accuracy, let us say, as the performance calculations of a 3-phase 60-cycle induction motor. If those who have made the field of human relations their life work are unable to come to any general agreement on the basic principles or laws of their field, how can an engineer be expected to be in any way more competent?

All this is a prelude to what I think Institute policy should be: strict attention to the advancement and improvement of the art of electrical engineering; co-operation with other engineering organizations in engineering studies; no activity by the Institute in any field in which an electrical engineer is not considered competent.

NORTON SAVAGE (A '41)

(Detroit Edison Company, Detroit, Mich.)

Which Way, America?

To the Editor:

In their addresses published in *Electrical Engineering* of April, Sir Ernest Benn and Dr. Harold E. Stassen have presented excellent summaries of the present condition of political economy in England and in the United States. W. C. Mullendore at the 1949 AIEE Pacific General Meeting, as well as numerous statesmen and others, have voiced similar criticisms during the past year.

If Americans honestly desire to put a stop to the present trend toward socialism, communism, dictatorship, and eventual serfdom, they must review the outstanding political events since the beginning of the 20th century in the United States, as Sir Ernest has done with respect to Britain. We must face the facts, and we must be willing to abandon fetishes and to forsake taboos.

While it was not then generally deemed of such evil portent as it has since proved to be, it must be remembered that it was an anarchist in Buffalo in 1901, who opened the door of the White House to an admitted radical and to a new regime—aye, a new dynasty in American politics.

The first decade of the 20th century in the United States was definitely characterized by: socialist oratory and yellow journalism, fomenting unrest and discontent among working people and intellectuals; trust-busting demagoguery; the initiative and referendum were adopted, circumventing representative government; the direct election of United States Senators was ratified, destroying control by the states over their only representatives in the national legislature; repeal of court decisions was advocated, to belittle the judicial branch of our government; and all these were climaxed with the 1912 campaign for a "third term" and triumphant dictatorship. Indeed, the American federation of sovereign states was thoroughly undermined during the progressive (?) first decade of the 20th century. The Roosevelt II regime of the fourth and fifth decades merely reaped the crop sown by its progenitor.

Near the beginning of the second decade, both Great Britain and the United States were inoculated almost simultaneously with what was then thought to be a health serum, but which has since proved to be a virulent disease. The 16th Amendment, authorizing Federal income taxes, was ratified about 1913, and appeared to be quite innocuous until the Roosevelt II regime assumed power in 1933. Since that time, the practically unlimited revenues from income taxes have been the chief means by which the Federal administration has been able to sell almost every kind of harmful nostrum and "ism" to our own people, and to give away whatever revenue is not squandered.

The 18th Amendment made law-breakers and outlaws of millions of our citizens. It was repealed, in order to restore a modicum of respect for law and order. The evil effects of the 18th Amendment were trivial and superficial in comparison with the devastation which has been wrought by the 16th Amendment.

The unbridled power of the Federal government "to lay and collect taxes on incomes, from whatever source derived," is responsible for the demoralization of our whole system of government—Federal, State, and local—while paltry handouts have hypnotized our citizenry. No Federal administration could indulge in current rates of extravagance, waste, bribery, and paternalistic usurpation, if it were denied its present power to confiscate, as do Russian communes, all but the barest minimum of the products of each citizen's toil.

Just as excision is the only cure for cancer, so is the outright repeal of the 16th Amendment of utmost importance. When the 16th Amendment shall have been repealed *in toto*, the following clause of Article I of the original Constitution will again become effective:

> Representatives and direct Taxes shall be apportioned among the several States which may be included within this Union, according to their respective Numbers, . . .

Obviously, repeal will not destroy any wealth, but it will restore the assessment of Federal taxes to the closer surveillance and control of the states.

Budget cuts and departmental reorganizations are merely palliative salves. Uncle Sam should submit to surgery, or else have his head examined, before he is committed to anarchy.

The AIEE is not a political forum for the airing of partisan views. Neither has the Institute any authority to advocate, or to oppose, a political issue. Nevertheless, the 30,000 American members of the Institute do cast votes, and they individually wield the power to influence their elected representatives in the Municipal, County, State, and Federal Governments which comprise our Republic.

LLOYD N. ROBINSON (F '25)

(Seattle, Wash.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

JET-PROPELLED AIRCRAFT POWER PLANTS. By J. P. Eames. Pacific Aero Tech., San Francisco, Calif., 1949. 121 pages, illustrations, diagrams, charts, tables, 8 by 5½ inches, fabrikoid, $3. Following a brief review of fundamentals, compressorless jet, turbojet, propjet, and pocketjet power plants are treated in a concise manner. Maintenance problems are discussed and construction materials are described. A glossary of terms is included.

HYDROELECTRIC HANDBOOK. By W. P. Creager and J. D. Justin. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1950. 1,151 pages, illustrations, diagrams, charts, maps, tables, 9¼ by 6 inches, cloth, $12.50. This standard work gives a comprehensive and detailed treatment of the problems involved in hydroelectric power developments and provides sufficient data for preliminary designs, estimates of costs, and reports. The first of four major sections covers the investigation and planning of a hydroelectric project. The second section discusses and compares the various types of dams and presents the general design methods involved in their construction. Conduits and powerhouses are covered in the third section. In the final section, the mechanical and electric equipment of a hydro plant and methods for its operation are dealt with. Owing to the extensive developments of the last 20 years, this second edition is considerably enlarged and has been largely rewritten.

ENGINEERING MECHANICS. By A. Higdon and W. B. Stiles. Prentice-Hall, Inc., New York, N. Y., 1949. 505 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $6.65. This basic text stresses the fundamental principles of engineering mechanics and the development of the ability to apply them. Equal emphasis is placed on statics and dynamics. Where possible, an action is illustrated by the use of free body diagrams or other pictorial and semigraphical aids as a supplement to the use of elementary calculus. Over 1,100 problems are included, of which about 100 are set up as illustrative examples.

ELEMENTARY PILE THEORY. By H. Soodak and E. C. Campbell. John Wiley and Sons, New York, N.Y.; Chapman and Hall, Ltd., London, England, 1950. 73 pages, diagrams, charts, tables, 8½ by 5½ inches, linen, $2.50. Presenting a declassified version of

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares biblographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

the lectures given by Dr. Soodak during the Clinton Laboratories Training Program, this book discusses the fundamental ideas associated with the homogeneous chain-reacting pile in which fast neutrons are produced by fission. Only simple mathematics are used, and illustrations are included to facilitate understanding of the physical and mathematical ideas involved.

ELECTRONIC ENGINEERING MASTER INDEX, January 1947 through December 1948. Electronics Research Publishing Company, 480 Canal Street, New York 13, N. Y., 1950. 339 pages, 10 by 7 inches, cloth, \$19.50. This volume is the third in a series which indexes electronic and allied engineering literature throughout the world. It contains more than 18,000 entries from over 230 of the major scientific magazines. Patent references are included as are many United States, British, and Canadian declassified documents. A bibliography of engineering books is also provided. The cumulative cross-index of subjects has been expanded and serves as a guide to the entire series.

ELECTRON-TUBE CIRCUITS. By S. Seely. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 529 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$6. This book provides an analytical method for the study of the electron-tube circuits, presents the various classes of circuits which find widespread application, and indicates, with examples, how to combine various types of circuits for specific purposes. Approximately one-half the content is of a radio-engineering character, the remaining material being extensively used in radar, television, pulse communication, and general electronic control.

APPLIED EXPERIMENTAL PSYCHOLOGY, HUMAN FACTORS IN ENGINEERING DESIGN. By A. Chapanis, W. R. Garner, C. T. Morgan. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1949. 434 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$4.50. Beginning with descriptive chapters on how human beings see, hear, and make movements, this book then applies these principles to the designing of machines and instruments better suited for human use. Psychological capabilities and limitations are effectively related to physical factors. Space is also devoted to the presentation of elementary statistical procedures and to a consideration of fatigue and other important physiological factors in the working environment.

ASTM STANDARDS ON PETROLEUM PRODUCTS AND LUBRICANTS, prepared by ASTM Committee D-2, American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1949. 1,420 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, \$5.50 (cloth, \$6.15). The 125 standards in this volume include test methods, specifications, lists of definitions, and tentative recommended practices. Twelve proposed methods of test are appended. Subject groups covered are petroleum fuels, illuminating oils, lubricating oils, plant spray oils, cutting fluids, insulating oils, hydrocarbon solvents, and ASTM specified thermometers.

ADVANCED TIME-MOTION STUDY, HANDBOOK OF. By L. A. Sylvester. Funk and Wagnalls Company in association with *Modern Industry* Magazine, New York, N. Y., 1950. 273 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$5. Of value to industrial engineers and executives, this book presents human work in a 3-dimensional concept—the product of mechanical work, physical conditions, and the human element. It discusses and defines what work is, the concept of a fair day's work, and within what limits of accuracy human work is measureable. Specific information is given on the mechanics of recording and evaluating time-motion study observations, the conduct of the time-motion study engineer, and the administration of the time-motion study activity.

ENGINEERING FOR PRODUCTION. By W. Ernst, with an introduction by A. M. Greene, Jr. Research Press, Inc., Dayton, Ohio, 1949. Pages in sections, diagrams, charts, tables, $11^1/_2$ by $9^1/_2$ inches, fabrikoid, \$10. Linking the mechanical engineer and the workshop, this manual contains all the essential information required for the preparation of shop working drawings for structures, machines, and useful products. It provides a ready reference for useful engineering information and data design. In addition to drafting technique there are two sections on the characteristics of metals, and threads and thread connections, gearing, and power transmission are also covered.

MACHINE TOOLS FOR ENGINEERS. By C. R. Hine. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 355 pages, illustrations, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, \$3.50. Based on courses developed at Rensselaer Polytechnic Institute, this book introduces the student to the fundamentals of machine tools and production processes. It gives a descriptive and analytical treatment of all types of machine tools, how they are used, what they can do, and what their limitations are. Some of the ways in which machine tools affect design of any product are discussed. The important machining processes are also covered.

ELECTRIC CIRCUIT THEORY. By H. Tropper. Longmans, Green and Company, London, England; New York, N. Y.; Toronto, Ontario, Canada; 1949. 164 pages, diagrams, $8^3/_4$ by $5^3/_4$ inches, cloth, \$2.75. Intended as a text for senior electrical engineering students, this book provides a unified account of some of the fundamental aspects of circuit theory. It shows how the solution of many network problems may often be simplified by the application of a few specific theorems. The treatments of steady-state and transient theory are based on the "superposition principle." A knowledge of elementary a-c theory is assumed.

ELECTRICAL FUNDAMENTALS, CIRCUITS, AND MACHINES FOR ENGINEERS. By R. W. Ahlquist. Pitman Publishing Corporation, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 400 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, cloth, \$5. Intended for students not majoring in electrical engineering, the book presents a survey of the field covering the fundamentals of potential difference, circuits, magnetic and electric fields, machines, and the concepts of power and energy. Special topics included are nonlinear elements, the principle of superposition, force upon an electron in a magnetic field, induced and dielectric heating, dynamic braking and plugging, the magnetic coupling and motor control. The MKS system is used throughout.

ELECTROPLATING. By A. H. Sanders. International Textbook Company, Scranton, Pa., 1950. 118 pages, illustrations, diagrams, charts, tables, $8^1/_4$ by $5^1/_2$ inches, cloth, \$2.75. A guide for both the novice and the practical electroplater, this book covers methods and materials for the processes of cleaning, pickling, coloring, and plating. Basic theory is discussed, and the last chapter is devoted to plating for the hobbyist.

ENGINEERING REPORTS. By L. A. Rose, B. B. Bennett, and E. F. Heater. Harper and Brothers, New York, N. Y., 1950. 341 pages, diagrams, charts, tables, $9^1/_2$ by $6^1/_4$ inches, linen, \$3. Written for both the engineering student and the practising engineer, this book deals with the problems connected with the conveying of facts and judgments on a technical level. It stresses the doctrine that effective reports are based on sound craftsmanship. Both written and oral reports of many kinds are considered together with a discussion of the limitations as well as the virtues of each as a medium of communication. Every step in the process of preparing technical reports is developed. Unusual assistance is given with the preparation of illustrations and to nonbibliographic sources of information.

FUNDAMENTALS OF DISCHARGE TUBE CIRCUITS. By V. J. Francis. Methuen and Company, Ltd., 36 Essex Street, Strand, London, W.C.2, England, 1948. 134 pages, diagrams, charts, $6^3/_4$ by $4^1/_4$ inches, cloth, \$1.50. Discusses the more important fundamental properties of discharge tubes in relation to the circuits in which they are used. Following a review of the discharge tube as a circuit element, there are chapters on operation on D-C supplies, dynamic characteristics, voltage and current wave forms on a-c supplies, operation on a-c supplies, and typical discharge lamp circuits with general principles of design.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Proceedings of Annual Meeting, Engineering College Research Council. A symposium of 12 papers on Instrumentation for Engineering Research highlights the *Proceedings* of the 1949 Annual Meeting, Engineering College Research Council, American Society for Engineering Education. Copies of the illustrated 140-page report may be obtained from the Chairman of the Engineering College Research Council, State University of Iowa, Iowa City, Iowa, at \$2 each.

Practical Factors in Applying Insulating Varnishes. Covers the subject of electrical insulating varnishes and presents conclusions based on broad experience in this country and in Europe. 12 pages. Copies are available at 25 cents each from V. W. Palen, Bureau of Public Information, New York University College of Engineering, New York 53, N. Y.

Subject Outline of the Unpublished Applications for Patents Filed at the German Patent Office—1940–1945. A new guide to wartime German patent applications which may now be used freely in Allied countries indexes 200,000 German applications filed in the Berlin Patent Office over the period 1940 to 1945. The guide breaks the patents down into 13 major industrial groups, 89 classes, and 500 subclasses. Copies are available on request from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

Table of Powers of Complex Numbers, by H. E. Salzer. Exact values of powers of complex numbers are given in Cartesian form for powers from 1 through 25 and for arguments with real and imaginary parts ranging separately from 0 to 10 in unit steps. The table is arranged essentially in order of magnitude of the distances of the argument values from the origin in the complex plane. 44 pages. Copies are available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 25 cents each.

Lighting for Flour Mills. A report based on surveys of lighting levels in various work areas from the roll floor and other processing departments to inspection and final weighing and bagging areas. Eight pages. Single copies are available at 50 cents each with quantity prices upon application from the Publications Office, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y.

Determination of Curvature by an Osculometer, by H. L. Curtis. The curvature and second derivative at any point of a plotted curve can be quickly determined by means of an easily constructed device known as an osculometer. Four pages. Five cents a copy. Available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.